Halley
IN PICTURES

ASTRONOMY

September 1986
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Halley: What We Learned

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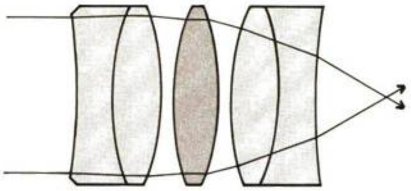
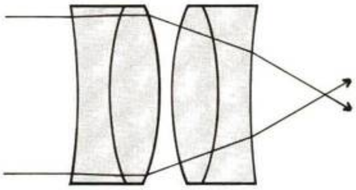
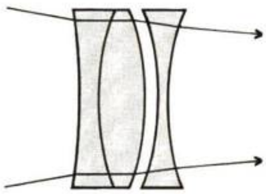


Meade 5-element Super Plössl design: the central lens element enables significant reductions in chromatic aberration and edge-distortions over other premium Plössl designs.



Other premium Plössls: include only the traditional 4-elements.



Meade Series 4000 Barlows: 3 elements, air-spaced, instead of the standard 2 non-air-spaced elements.

Series 4000 Eyepieces and Barlows

Super Plössls (5-elements)	APPARENT FIELD	BARREL DIA.	PARFOCAL
6.4mm	52°	1¼"	Yes
9.7mm	52°	1¼"	Yes
12.4mm	52°	1¼"	Yes
15mm	52°	1¼"	Yes
20mm	52°	1¼"	Yes
26mm	52°	1¼"	Yes
32mm	52°	1¼"	Yes
40mm	44°	1¼"	No
56mm	52°	2"	No
Super Wide Angles (6-elements)			
13.8mm	67°	1¼"	Yes
18mm	67°	1¼"	Yes
24.5mm	67°	1¼"	Yes
32mm	67°	2"	No
40mm	67°	2"	No
Ultra Wide Angles (8-elements)			
4.7mm	84°	1¼"	Yes
6.7mm	84°	1¼"	Yes
8.8mm	84°	1¼" & 2"	Yes
14mm	84°	1¼" & 2"	No
Barlow Lenses (3-elements, air-spaced)			
#140 2X Telenegative Amplifier		1¼"	Yes
#142 2.8X Telenegative Amplifier		1¼"	Yes

Meade 2" Mirror Diagonal: For attachment to Schmidt-Cassegrain telescopes, the 2" Mirror Diagonal permits use of Series 4000 eyepieces with 2" barrels. The 1/10-wave-flat Pyrex mirror, manufactured at the Meade Costa Mesa optical facility, is multi-coated with enhanced aluminum for maximum reflectance. An adapter for 1¼" eyepieces is included.

Where To Buy: Meade Series 4000 eyepieces and Barlows are available from over 600 authorized Meade dealers in the U.S.A. and Canada. Call us toll-free (see below) for your nearest dealer.

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ASTRONOMY

Vol. 14, No. 9

September 1986

The World's Most Beautiful Astronomy Magazine

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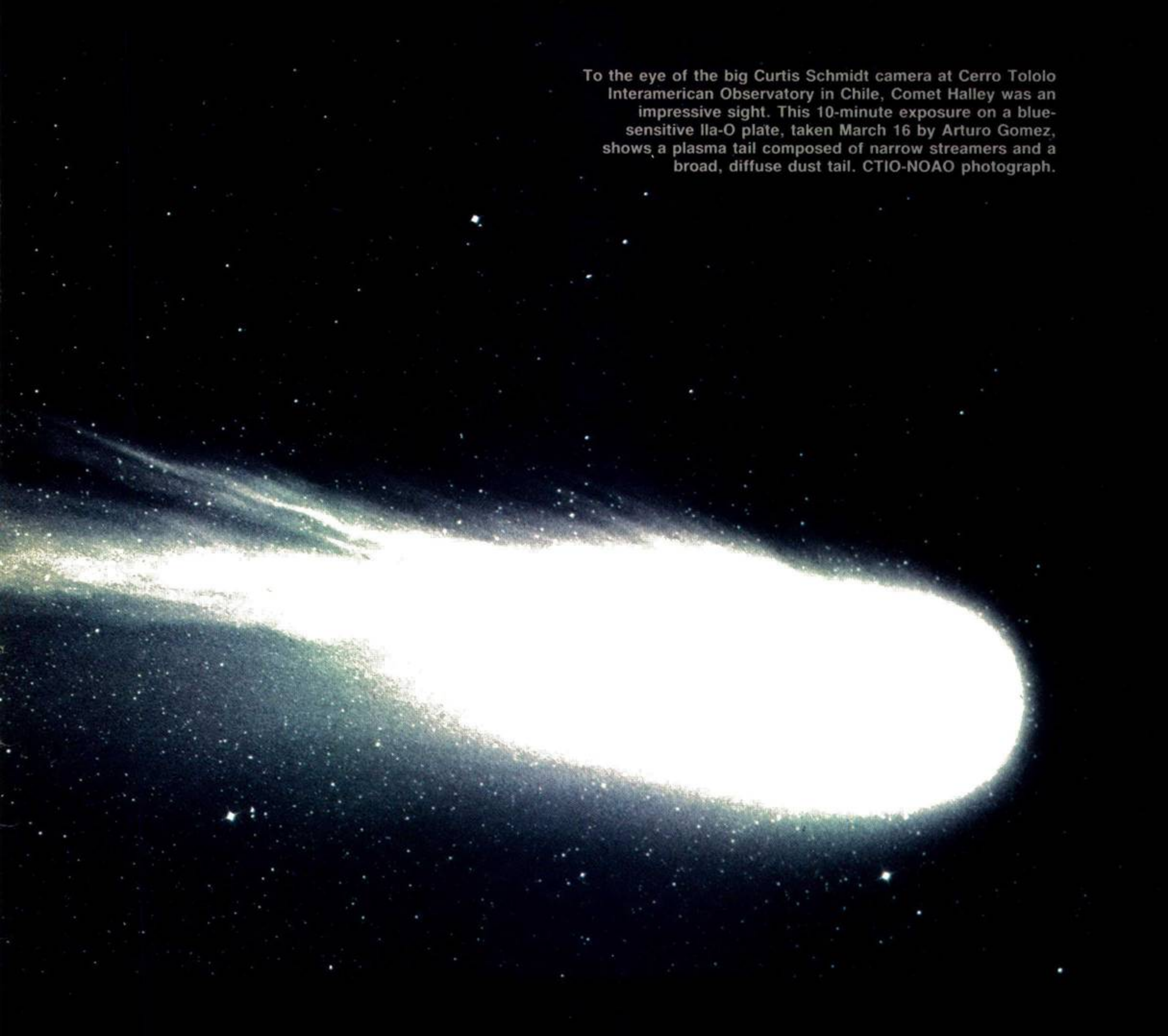
Cover: That cold, crisp morning gained a special magic when you finally saw Comet Halley glowing above the first blush of dawn. Artist Bruce Bond has captured that sublime and passing moment for our readers on the cover of this special "What We Have Learned About Halley" issue of ASTRONOMY. These pages: On Halley's night of greatest brightness, Barney Magrath guided his piggybacked camera for 10 minutes to capture this image. He used a 105mm f/4 and Fuji RD100 film.

ASTRONOMY (ISSN 0091-6358) is published monthly by AstroMedia, a division of Kalmbach Publishing Co., 1027 N. Seventh St., Milwaukee, WI 53233. Copyright © 1986 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Second class postage paid at Milwaukee, WI and additional mailing offices. POSTMASTER: Send address changes to ASTRONOMY, 1027 N. Seventh St., Milwaukee, WI 53233. Questions about subscriptions and product orders: (414) 272-2060 weekdays, 8:30am - 4:45pm. Allow six to eight weeks for new subscriptions and changes of address. New subscriptions start with current issue. Subscription price: 1 year, $21.00. All foreign: add $5.00 per year; please remit in U.S. funds. Send editorial and business inquiries and submissions to the address above. Telephone: (414) 272-2060. Not responsible for unsolicited materials. ASTRONOMY is indexed in *The Reader's Guide to Periodical Literature*. Microfilms of ASTRONOMY available from University Microfilms, Inc., 300 N. Zeeb Rd., Ann Arbor, MI 48106 and Bell & Howell Company, Old Mansfield Rd., Wooster, OH 46691. Printed in the U.S.A.

What Have We Learned From

COMET

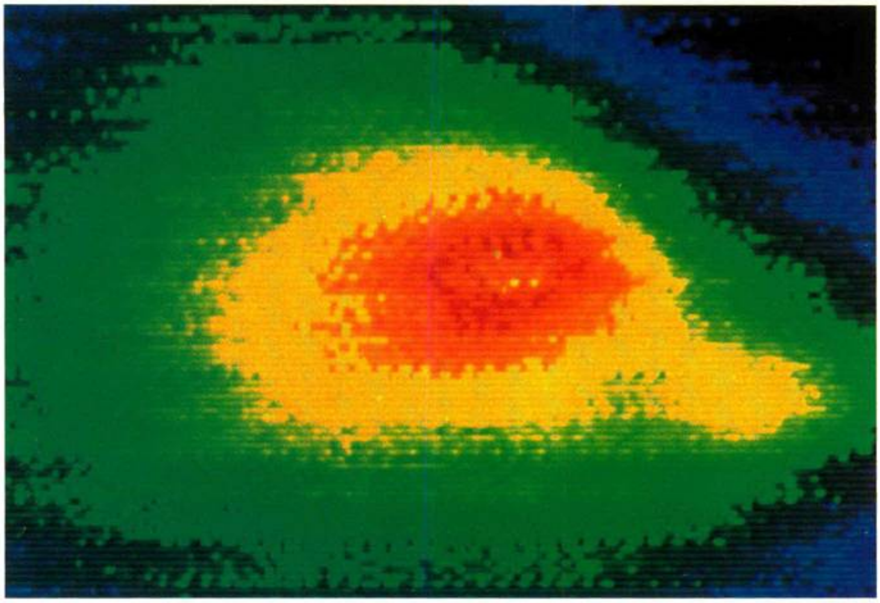
by F



To the eye of the big Curtis Schmidt camera at Cerro Tololo Interamerican Observatory in Chile, Comet Halley was an impressive sight. This 10-minute exposure on a blue-sensitive IIa-O plate, taken March 16 by Arturo Gomez, shows a plasma tail composed of narrow streamers and a broad, diffuse dust tail. CTIO-NOAO photograph.

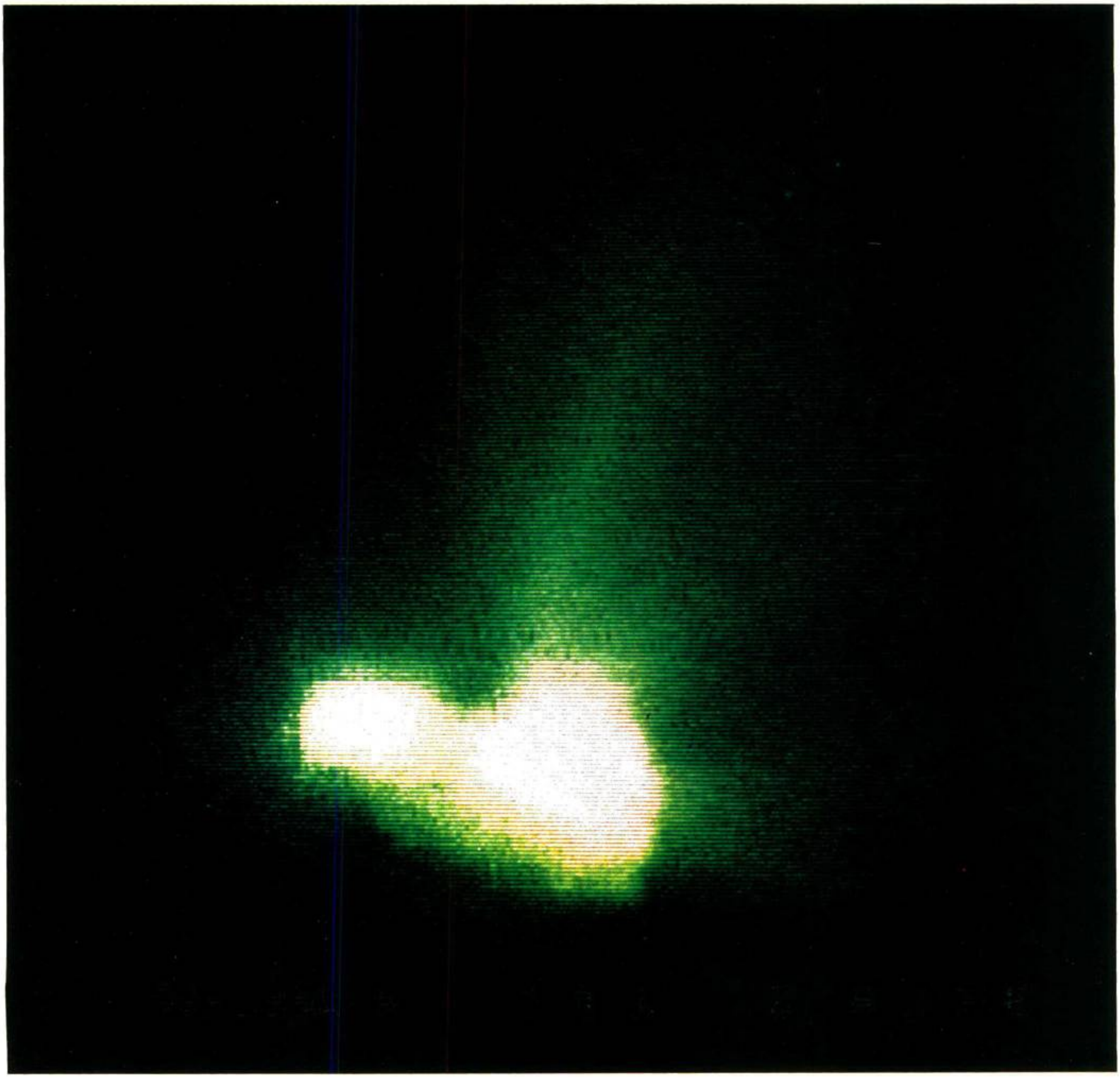
ichard Berry and Richard Talcott

HALLEY?



Top: On March 6, a television camera aboard the VeGa 1 spacecraft returned image data that has allowed Soviet scientists to evaluate the size, shape, and reflectivity of the nucleus and follow rapid changes in the innermost part of the coma. The two bright centers, which in the days immediately following the flyby provoked speculation that the nucleus might be double, represent the two brightest jets coming from the nucleus, which is dark and possibly obscured by dust. Photo courtesy Lou Friedman, The Planetary Society.

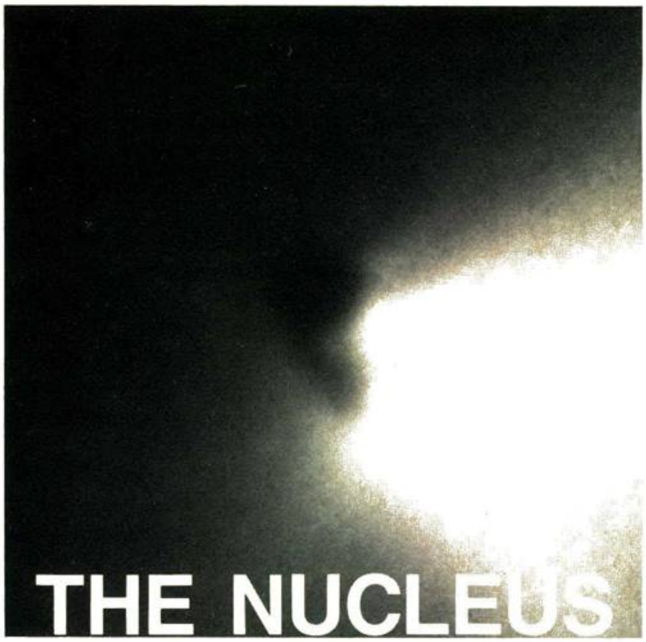
Bottom: VeGa 2's camera picked up a considerably more recognizable image of Halley's nucleus on March 9, showing distinct jets emerging from one small part of the nucleus. The largest jet appears to be made up of several components rather than a single spray. Photo courtesy Steve Edberg, International Halley Watch.



As the huckster's call — "Step right up, folks, it's a once-in-a-lifetime experience" — fades into astronomical memory, you may wonder: What was it all about? Why the hoopla and why the hype, why the excitement and why the pronouncements? Was it all worth it? If we take at face value that we set out to learn something about comets from Comet Halley, then what *did* we learn from Comet Halley?

Well, it turns out that we've learned a lot. Although it will be years before all the data collected have been thoroughly analyzed, astronomers have already begun announcing their findings.

Oddly enough, it's results from the highly complex experiments aboard the Russian, European, and Japanese spacecraft that have been reported, rather than the much simpler ground-based studies. From a ground-based astronomer's point of view, Halley is only one comet among many, and photographs and spectra can be studied at leisure long after the comet has vanished. Results from space experiments come quickly because they are narrowly focused on answering one or two specific scientific questions, and also because national prestige demands that results, any results, be announced as soon as possible.



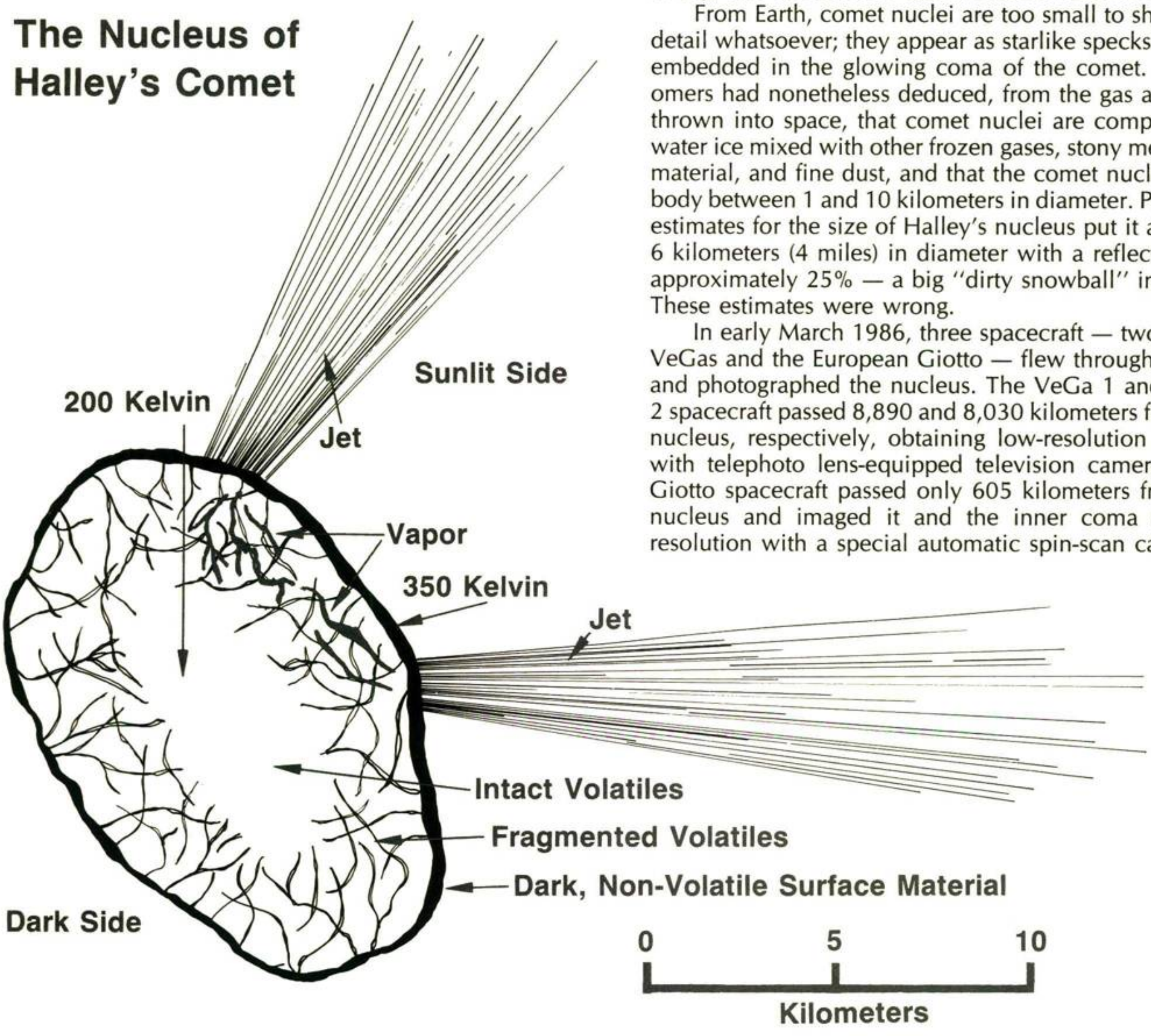
THE NUCLEUS

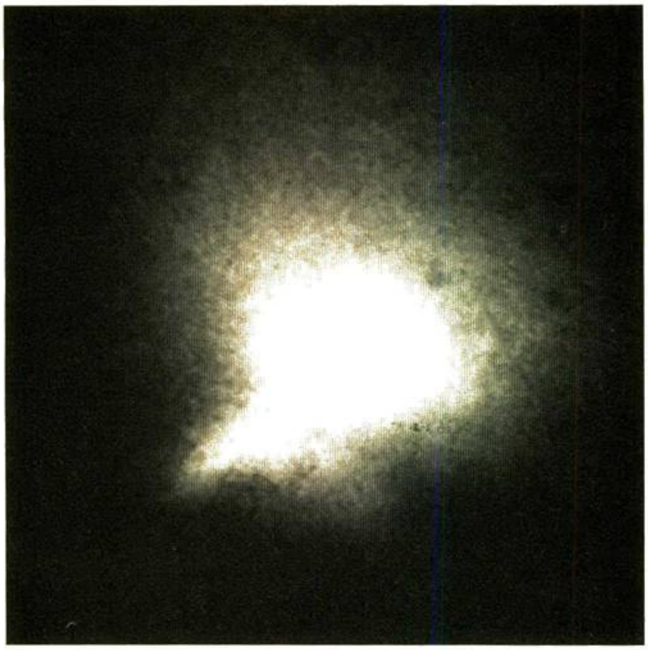
Although the long tails, the bright coma, and the enigmatic jets of a comet provoke astronomers' curiosity, it's the nucleus they really want to know about. But, sad to say, it is the nucleus that we know least about.

From Earth, comet nuclei are too small to show any detail whatsoever; they appear as starlike specks of light embedded in the glowing coma of the comet. Astronomers had nonetheless deduced, from the gas and dust thrown into space, that comet nuclei are composed of water ice mixed with other frozen gases, stony meteoritic material, and fine dust, and that the comet nucleus is a body between 1 and 10 kilometers in diameter. Pre-flyby estimates for the size of Halley's nucleus put it at about 6 kilometers (4 miles) in diameter with a reflectivity of approximately 25% — a big "dirty snowball" in space. These estimates were wrong.

In early March 1986, three spacecraft — two Soviet VeGas and the European Giotto — flew through Halley and photographed the nucleus. The VeGa 1 and VeGa 2 spacecraft passed 8,890 and 8,030 kilometers from the nucleus, respectively, obtaining low-resolution images with telephoto lens-equipped television cameras. The Giotto spacecraft passed only 605 kilometers from the nucleus and imaged it and the inner coma at high resolution with a special automatic spin-scan camera.

The Nucleus of Halley's Comet





During an observing run on the 2.3-meter telescope at the Mount Stromlo-Siding Spring Observatory in Australia, University of Notre Dame astronomers Terrence Rettig, Randal Ruchti, and Barry Baumbaugh recorded rapidly changing jet activity in Halley's inner coma. To record the comet in real time, they used a CCD television camera with a microchannel-plate image intensifier tube. This image, taken on the night of March 25/26, shows a region some 30,000 kilometers across. In addition to obtaining images of scientific value, the group was able to provide live TV coverage of the comet to Australian National Television and the National Geographic Society.

9 mi. long. 4½ mi. wide, thick

The Russian images, which in their raw form appear unsharp, reveal the nucleus as an irregular, potato-shaped body some 14 kilometers long and 7.5 kilometers thick by 7.5 kilometers wide. In those images, the nucleus appears to be very dark, reflecting roughly 4% of the light falling on it. This is as dark as finely ground charcoal or carbon black. The images show this dark body enveloped in a cloud of dust and sometimes obscured by it. Of the several thousand images obtained, the seventy best will be extensively processed, and from these the Russian investigators expect to be able to reconstruct the complete three-dimensional shape of the nucleus.

The Giotto images suggest a somewhat different shape for the nucleus, though Giotto did not have as good a viewing angle as the VeGas. In the images, the nucleus appears "as a solid object of irregular shape visible as a dark silhouette against background light scattered by dust," according to the Giotto imaging team scientists. The profile of the nucleus is 15 kilometers long by possibly as much as 10 kilometers wide. Dust surrounding the nucleus makes finding the sunlit edge of the nucleus difficult, so the width of the nucleus cannot be determined with any precision. The net result is that, although they are considerably sharper than the VeGa pictures, the Giotto images are difficult to interpret.

The VeGa images reveal almost nothing of the surface of the nucleus. In the Giotto images very little can be seen on the dark side of the nucleus and what can be seen may be imaging artifacts rather than surface detail, according to the camera team. However, the profile of the nucleus seen in silhouette against the inner coma in the Giotto images shows slopes of up to 15 degrees, suggesting a fairly rugged terrain. Another clue is that the terminator between the light and dark hemispheres of the nucleus is scalloped, an indication that the surface has features, perhaps crater-like depressions, fumaroles, or rolling hills ranging in size from a hundred meters to a kilometer across.

Both the VeGa and the Giotto images show something not entirely unexpected: jets coming from the nucleus. In the classic "dirty snowball" model for comet nuclei, the comet's coma and tail are composed of gas that has evaporated and dust that has been blown away from the surface of the nucleus. Before the flybys most astronomers assumed that the gas would evaporate from the surface uniformly, carrying dust particles with it as they were uncovered in a process informally known as an "inverse snowstorm." Although ground-based observations showed local brightenings in the inner coma, these jets were generally passed off as minor anomalies in the smooth outflow of gas and dust from the nucleus to the coma.

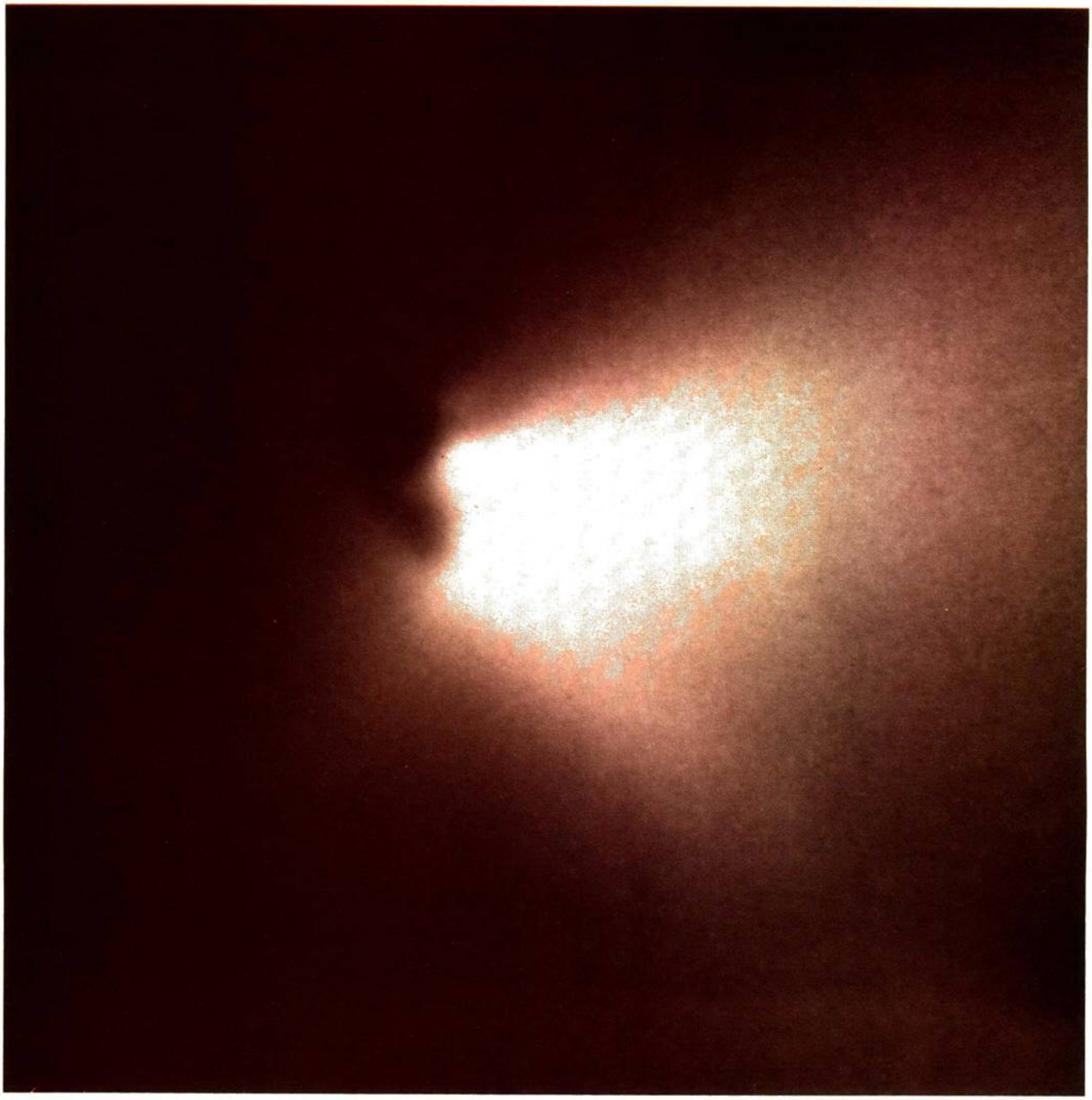
Even before the flybys it was becoming apparent that this model didn't really work. A study of the night-to-night variations of features in the coma, based on photographs taken in 1910 (see "Mining Old Silver," ASTRONOMY, October 1985), led astronomers Steve Larson and Zdenek Sekanina to predict jets of gas and dust from Halley's nucleus. They even prepared a map showing where the jets had been in 1910.

The spacecraft showed virtually all of the gas and dust vents from six or seven small areas on the surface as narrow jets. One of the jets is much larger than any of the others, and it and the second largest jet account for the bulk of Comet Halley's gas and dust emission. The rest of the surface appears to be completely inactive.

All the jets appear on the sunward side of the nucleus, and as best as can be determined none are found on the dark side. The jets cover roughly 10% of the surface of the nucleus. The two VeGa spacecraft viewed Halley's nucleus from a wide range of angles and detected at least five jets. Both the Russian and the European images show that the largest jet and quite possibly several of the smaller jets have internal structure, suggesting that the jets are clusters of smaller jets or that they come from multiple sources.

At least in the case of Comet Halley, the simple dirty snowball model is inadequate. At first it might seem that the ice in the nucleus must be very dirty for the surface to be as black as charcoal. However, suppose comet nuclei are aggregates of interstellar particles of water ice, organic material, and silicate dust that coalesced in the solar nebula when our solar system formed. When the nucleus heats up as Halley approaches the Sun, water and volatile organic materials evaporate out, leaving a skeleton of non-volatile organic materials and silicate dust full of holes where volatiles had been. Such porous structures absorb light very well and could explain why the nucleus appears jet black.

Because it's black, the nucleus should absorb sunlight and be quite warm. Infrared spectra of the nucleus obtained by VeGa 1's infrared spectrometer show that the temperature of the nucleus and the dusty cocoon that surrounds it is between 300 and 400 Kelvins — much too hot for a surface of bare ice. If the surface were ice, it could not be that hot because it would be cooled by evaporation.



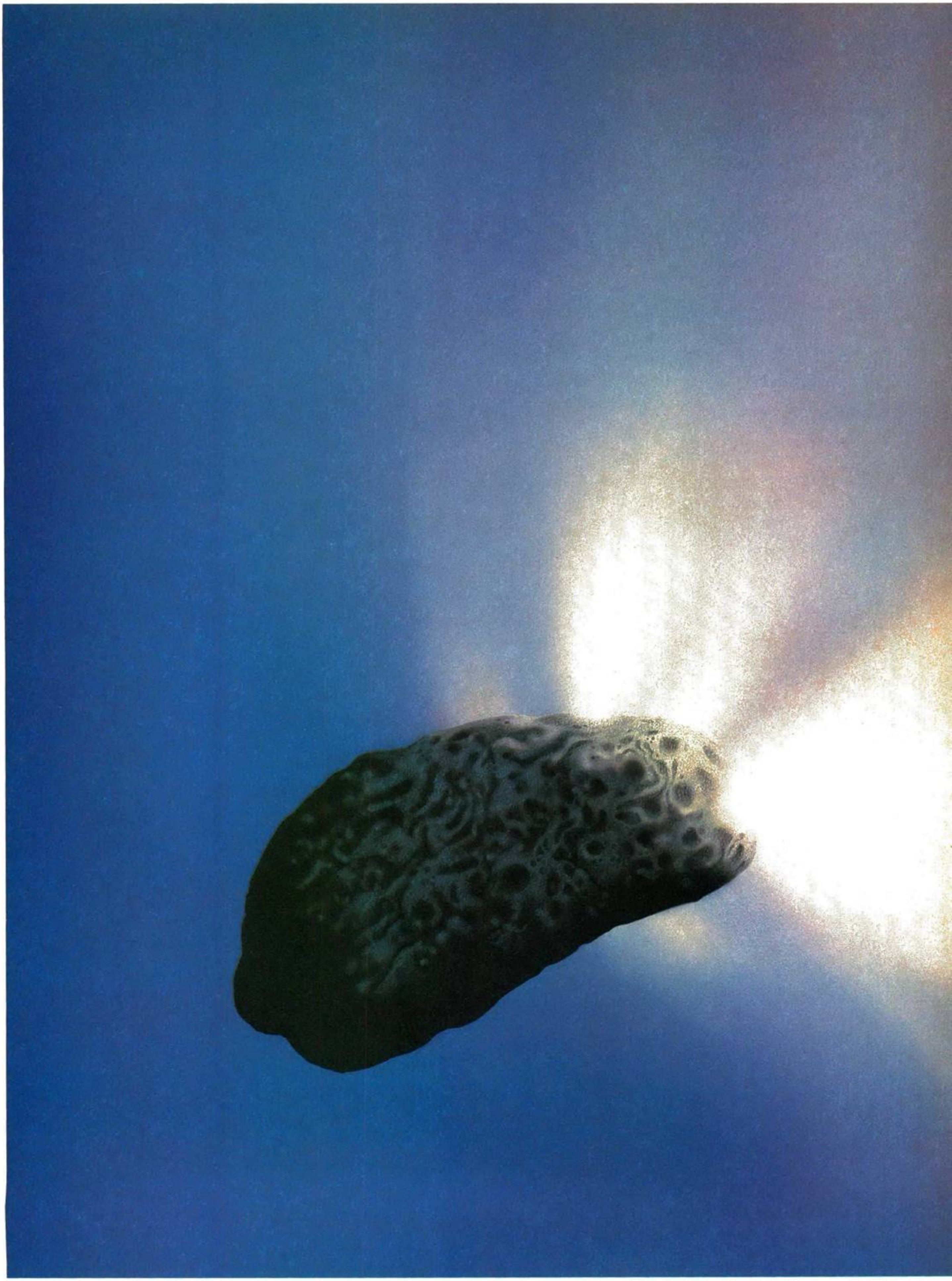
Though dark compared to the bright, sunlit jets emanating from it, Halley's nucleus posed for the European Space Agency's Giotto spacecraft on March 14. Giotto flew within 605 kilometers of the nucleus, directly measuring the composition and amounts of gas and dust in the inner coma. Photo courtesy Max-Planck-Institute für Aeronomie, © 1986 MPIA.

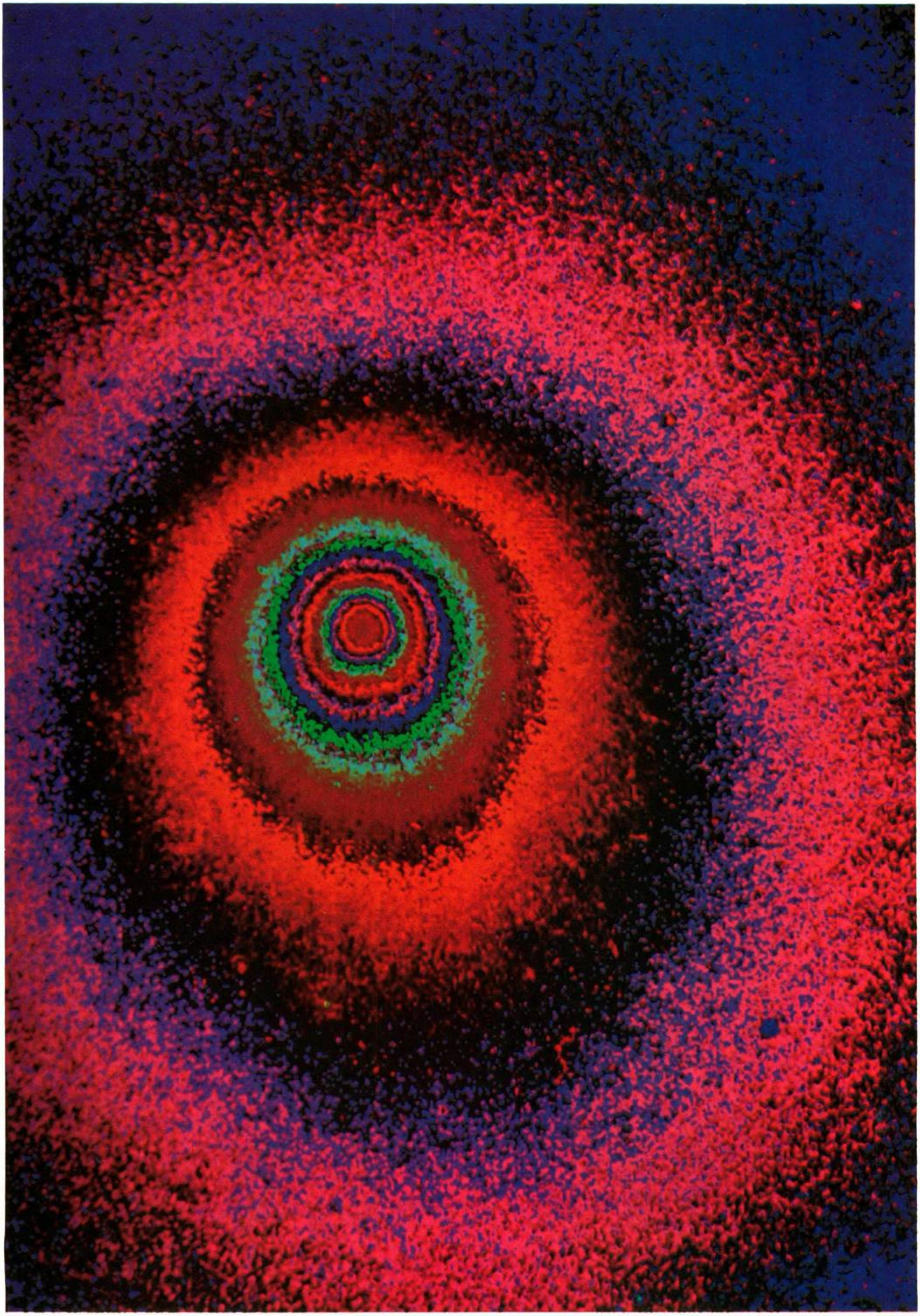
But according to the Soviet scientists, the high temperature is entirely explained if Halley's surface is mantled with what they call a "porous dark substance of low thermal conductivity" that keeps the interior cool.

Given this high surface temperature, there is further reason to think that loss of material from Halley is confined to the jets. The observed rate of mass loss — 5×10^{29} water molecules per second — is one-tenth of what a hot, bare icy nucleus should generate at the temperatures observed by VeGa. This implies that the crust protects the interior of the nucleus from heating and evaporating, and that crust is not dirty ice but some kind of residue that does not evaporate. The Giotto investigators conclude that the surface of Halley is covered with a "non-volatile, insulating crust of dark material."

Like most celestial bodies, comet nuclei rotate. The same 1910 study that had mapped the location of the nuclear jets showed that the features in the inner coma

Overleaf: This painting, based on the best available Giotto and VeGa images, shows the the nucleus of Halley's Comet as it might appear to astronauts in the year 2061 as they maneuver toward a rendezvous with the comet. Painting by Bruce Bond.

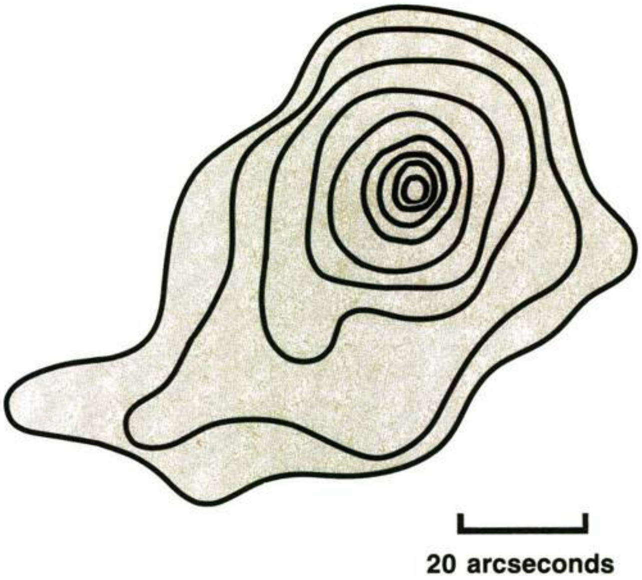




vary with a 53-hour period. More recently, the Japanese Sakigake and Suisei spacecraft showed that the hydrogen gas coma surrounding the comet "breathes" (expands and contracts) with a similar period, and the VeGa spacecraft images are consistent with the 53-hour rotation period, give or take a few hours.

The rotation, coupled with the lack of any active jets on the dark side of the nucleus, may eventually give us clues about the unseen interior and overall structure of Halley's nucleus. As the nucleus rotates, new areas enter the "daytime" side, heat up, and presumably become active. Active areas rotate into darkness and turn off. The speed of turn-on and turn-off will depend strongly on the insulating and heat-absorbing properties of the crust, giving astronomers a "handle" on its thickness and composition.

To the Giotto imaging team, the irregularity of the shape of the nucleus and the jets suggest that the interior is not uniform or that the crust varies considerably in thickness. Over successive apparitions, the most volatile regions of the nucleus evaporate more rapidly than non-volatile parts, leaving cracks, honeycomb structures, or even gaping caverns in the interior. As the interior is depleted, the crust may crack and collapse inward under the force of gravity or sections may blow off into space, depending on the strength and thickness of the crust. Any or all of these processes may play roles in forming the irregular surface that the spacecraft images hint is there.



Above: This contour map of Halley shows the distribution of infrared emission from its dust coma as it appeared on November 18, 1985. The map shows the dust coma's similarity to the hydrogen coma image opposite, particularly the decrease in density with increasing distance from the nucleus and the tailward elongation caused by solar radiation pressure. NASA/Marshall Space Flight Center data courtesy Roger Knacke.

Left: This false-color ultraviolet image showing the hydrogen coma of Comet Halley was taken on March 13, 1986, from a sounding rocket 300 kilometers above Earth. Variations in the strength of Lyman-alpha emission from neutral hydrogen atoms reflect the outwardly decreasing density of the coma. The coma extends tens of millions of kilometers from the nucleus and is elongated in the direction away from the Sun due to solar radiation pressure on the hydrogen atoms. Naval Research Laboratory photo.

THE COMA

Surrounding a comet's nucleus is its coma, or "atmosphere," an expanding, roughly spherical cloud of gas and dust that has evaporated from the Sun-heated nucleus. Traditional visual observations show that a typical comet's coma extends 100,000 kilometers into space from the nucleus, but space-based imagery shows a much larger halo of hydrogen gas that extends many millions of kilometers.

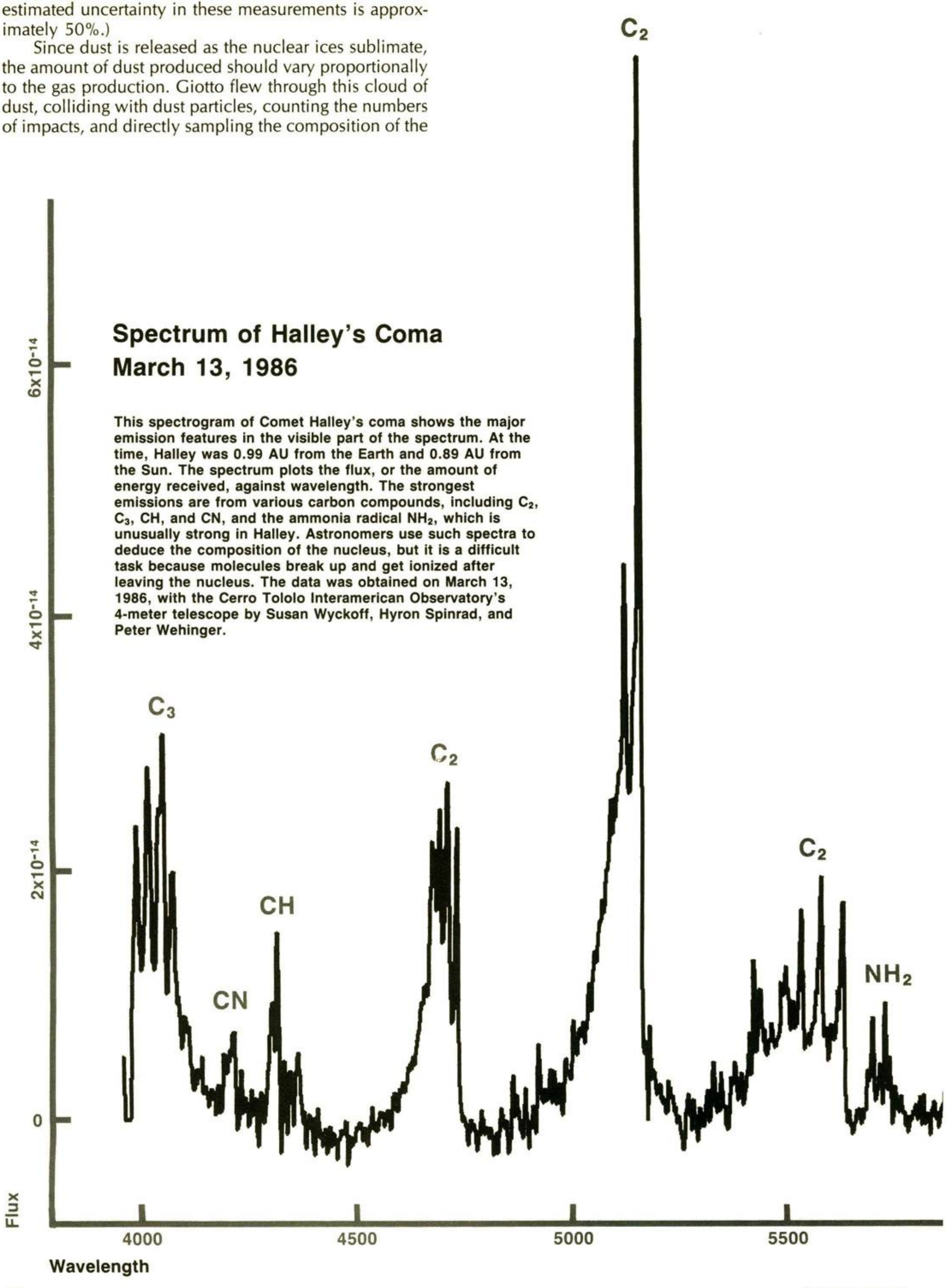
The coma is of interest to astronomers for two principle reasons. First, the composition of the gases in the coma must reflect the composition of the nucleus, since that is where the gas comes from. Second, the interaction of the coma with sunlight, the solar wind, and the magnetic fields in the space around the comet allows us to learn about both comets and the conditions in interplanetary space and to test our understanding of the chemistry and physics involved.

The Giotto probe flew deep into Halley's coma, measuring the amount of gas and its composition at distances down to a few thousand kilometers from the nucleus. Roughly 80% of the molecules in the coma turn out to be water, and most of the remaining 20% are molecules of carbon dioxide. At a distance of 1,000 kilometers from the nucleus, the instruments reported 47 million water molecules per cubic centimeter flowing outward from the nucleus with a speed of 900 meters per second. The total amount of gas given off was measured as 6.9×10^{29} molecules per second.

(To put these figures in perspective, air at sea level has 1.6×10^{19} molecules per cubic centimeter, which makes it 300 billion times denser than Halley's coma, the speed of outflow is some 2,000 miles per hour, and the loss of mass from the nucleus is roughly 25 tons per second.)

VeGa project scientists were able to estimate the total gas production rate from the measured distribution of neutral gas density and arrived at a figure of 1.3×10^{30} molecules per second. At the time of the Giotto encounter the production rate had fallen to half that figure. (The estimated uncertainty in these measurements is approximately 50%.)

Since dust is released as the nuclear ices sublimate, the amount of dust produced should vary proportionally to the gas production. Giotto flew through this cloud of dust, colliding with dust particles, counting the numbers of impacts, and directly sampling the composition of the



Spectrum of Halley's Coma
March 13, 1986

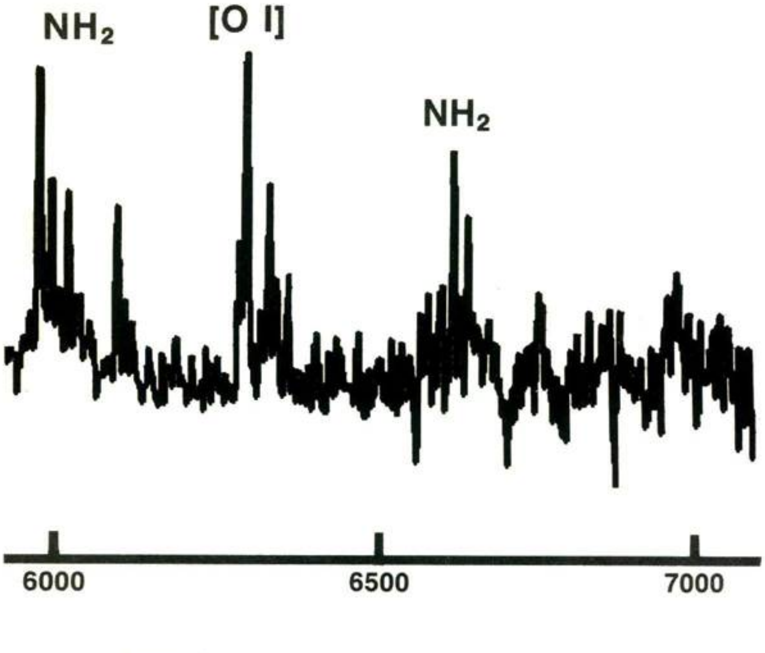
This spectrogram of Comet Halley's coma shows the major emission features in the visible part of the spectrum. At the time, Halley was 0.99 AU from the Earth and 0.89 AU from the Sun. The spectrum plots the flux, or the amount of energy received, against wavelength. The strongest emissions are from various carbon compounds, including C_2, C_3, CH, and CN, and the ammonia radical NH_2, which is unusually strong in Halley. Astronomers use such spectra to deduce the composition of the nucleus, but it is a difficult task because molecules break up and get ionized after leaving the nucleus. The data was obtained on March 13, 1986, with the Cerro Tololo Interamerican Observatory's 4-meter telescope by Susan Wyckoff, Hyron Spinrad, and Peter Wehinger.

dust particles. Altogether, the dust instrument team found that Giotto collided with upward of 150 milligrams of dust in its passage through the coma, and they determined that Halley's rate of dust ejection was 3 tons per second. This means that Halley ejects one-eighth as much dust by mass as it does gas (i.e., water and carbon dioxide), which is consistent with Halley's generally accepted classification as a moderately dusty comet.

Instruments aboard both VeGas and the Giotto spacecraft returned mass spectra of thousands of comet dust particles. The bulk of dust particles — roughly 80% of them — contain abundant hydrogen, carbon, nitrogen, and oxygen, with some sulfur, and they appear to have a low-density, or "fluffy", structure. These have been tentatively identified as radiation-damaged ice by the dust team scientists. The remaining particles contained low-mass atoms but were also rich in sodium, magnesium, silicon, calcium, and iron. This minority of particles resembles carbonaceous chondrite material, but not so closely that carbonaceous chondrites can fully explain their composition.

Surprisingly, in spite of their proximity to the nucleus, the Giotto and VeGa probes were not in the best position for measuring production rates. Because they flew so close to the nucleus, they were more susceptible to localized fluctuations than were more distant observers. All three probes were also limited by the high speed of the encounters to a "snapshot" of Halley, and so were unable to observe variations in gas and dust production rates. Hinted at by the spacecraft flybys, the full extent of variability became apparent only in longer studies.

During the week of March 9 to 16, the Earth-orbiting International Ultraviolet Explorer (IUE) satellite monitored the gas production of Halley in conjunction with the spacecraft flybys. (A major advantage of such distant observations is that small, local effects are averaged out.) Major variations in the gas output of Halley occurred in as little as one or two hours. The observations confirmed that a strong outburst took place at about the time VeGa 2 penetrated the coma, while during the Giotto flyby the nucleus was close to minimum activity. Water production rates, which should be about 80% of the total gas, were estimated at 5.6x10^{29} molecules per second during the VeGa 2 flyby and 5.2x10^{29} molecules per second at Giotto's closest approach, reasonably consistent with the results from those spacecraft.



Monitoring Halley on a daily basis beginning in mid-February, astronomers at the European Southern Observatory in La Silla, Chile, were able to correlate the production rates determined by the spacecraft with their own CCD images. Among the most complete sets of observational records, the La Silla data also recorded evidence of substantial variations from day to day.

Even shorter term variations were observed by a group of researchers from the University of Notre Dame. Using a high speed CCD Electronic Camera, they saw variations in periods ranging from shorter than a second to several seconds. These rapid fluctuations covered too large an area to be caused by any solar wind phenomena. The researchers are currently exploring a number of possible explanations.

The data set being compiled by the International Halley Watch will allow a detailed description of production rates as a function of heliocentric distance. Such data, which were first obtained while Halley was some 5 AU from the Sun, have been collected through the perihelion observations of Pioneer-Venus and will continue until the comet is once more too faint for measurement. This will allow comparison to the theoretical prediction that sublimation should vary inversely as the square of solar distance. While the variations rule this out as a detailed description, it will be interesting to know whether the general trend holds.

As the Giotto images revealed, the terminal velocity of the material released by the jets is about 900 meters per second. Since the escape velocity from a comet such as Halley is generally 1 meter per second or less, any such material released will quickly be lost from the nuclear region.

As these gas molecules travel away from the nucleus they are subjected to a variety of processes that mask their original identity. In the inner coma, which is generally considered to be the inner 10,000 kilometers of the atmosphere, collisions between molecules and photodissociation (the breakup of a molecule caused by intense ultraviolet radiation from the Sun) destroy many of the original, or parent, molecules. Throughout the coma solar radiation is strong enough to ionize (strip an electron from) both atoms and molecules. The net result is that the gases found in the outer coma are not usually the same as the ones originally sublimated from the nucleus. Reconstructing the original composition requires detailed models of the chemical and physical processes taking place.

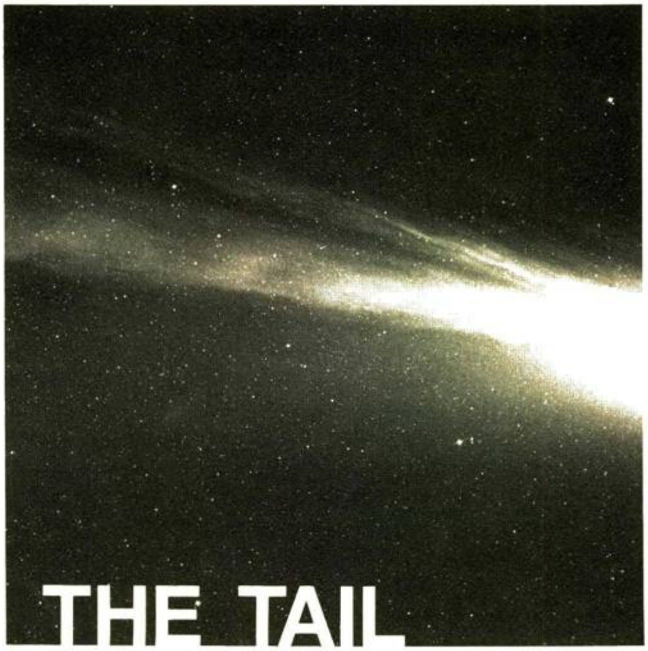
The dust coma is more straightforward, and the VeGa and Giotto probes added much new information about it. Both detected the outer boundary of the dust coma at between 250,000 and 300,000 kilometers from the nucleus. From there, the number density increased inversely as the distance squared until approximately 2,000 kilometers from the nucleus. As Giotto moved closer, the density increased at a greater rate, probably because it crossed a jet as it passed into the sunlit hemisphere. VeGa's instruments noted rapid fluctuations in the number of impacting particles as it came to closest approach, again presumably in response to nuclear jets.

The size of the observed dust also came as a surprise. Project scientists on both teams were expecting to observe almost no particles smaller than 10^{-14} grams, yet their dust detection systems measured masses down to 10^{-17} grams, at the lower limit of their equipment's sensitivity.

The largest part of Halley's atmosphere is the hydrogen coma. Composed of neutral hydrogen atoms, the halo glows in the light of Lyman-alpha at 1216 Angstroms in the ultraviolet part of the spectrum, visible only from spacecraft above Earth's atmosphere. The IUE satellite, the Pioneer-Venus Orbiter, the Japanese Suisei probe, and some sounding rockets devoted considerable time to observing this feature. Pioneer-Venus determined its extent near perihelion to be about 25 million by 35 million kilometers, making Halley temporarily the largest "object" in the solar system.

Suisei detected the hydrogen coma to be "breathing" — rhythmically changing in brightness — with a period of 2.2 days, reflecting the nucleus' rotation rate. This was an early indication that the nucleus was largely covered by a hard substance with sublimation occurring in concentrated jets.

One of the most unusual findings about Halley was the recording of radio emission by the Japanese spacecraft Sakigake. Passing through the outer part of the coma, the spacecraft's plasma-wave probe picked up emission in the 30 to 195 kiloHertz range. These emissions have been dubbed Cometary Kilometric Radiation and may arise from shock waves in the coma region resulting from turbulence in the solar wind.



THE TAIL

The solar wind plays a more significant role in the life of a comet than just creating radio emissions, however. Halley's Comet has now provided us with numerous insights into the relationship between comets and the solar wind.

The solar wind is a stream of charged particles (mostly protons and electrons) that flow away from the Sun because of the corona's high temperature and carry the Sun's magnetic field with it. Because charged particles cannot move easily across magnetic field lines, any ion that the solar wind encounters, such as those in the gas around a comet, will be swept up in the flow.

The solar wind normally travels outward at about 400 kilometers per second at 1 AU from the Sun, Halley's approximate distance during the Giotto flyby.

Right: This false-color image of Comet Halley was made with a 24-inch lens piggybacked on the University of Arizona's 61-inch Catalina Station telescope. The 10-minute CCD exposure was taken on January 17, 1986, through a red filter. Photo by Uwe Fink, Al Schultz, Mike DiSanti, and Robert Marcialis; courtesy Uwe Fink.

The first sign of an interaction between the comet and the solar wind occurred at a distance of about 7.5 million kilometers from the nucleus. From this distance to about 1.5 million kilometers lies the "outer region," characterized by large and irregular variations in the temperature and density of cometary electrons.

At 1,150,000 kilometers from the nucleus Giotto crossed the bow wave, marked by a relatively abrupt increase in density. (Some prefer to call it a bow shock, though the increase is not discontinuous as in the bow shock of a strong planetary magnetic field.) After taking Giotto's trajectory into account, the project scientists estimate that the bow wave is 400,000 kilometers from the nucleus in the sunward direction. This is some six to seven times larger than that found by the International Cometary Explorer (ICE) at Comet Giacobini-Zinner, reflecting the correspondingly greater gas production rate of Halley.

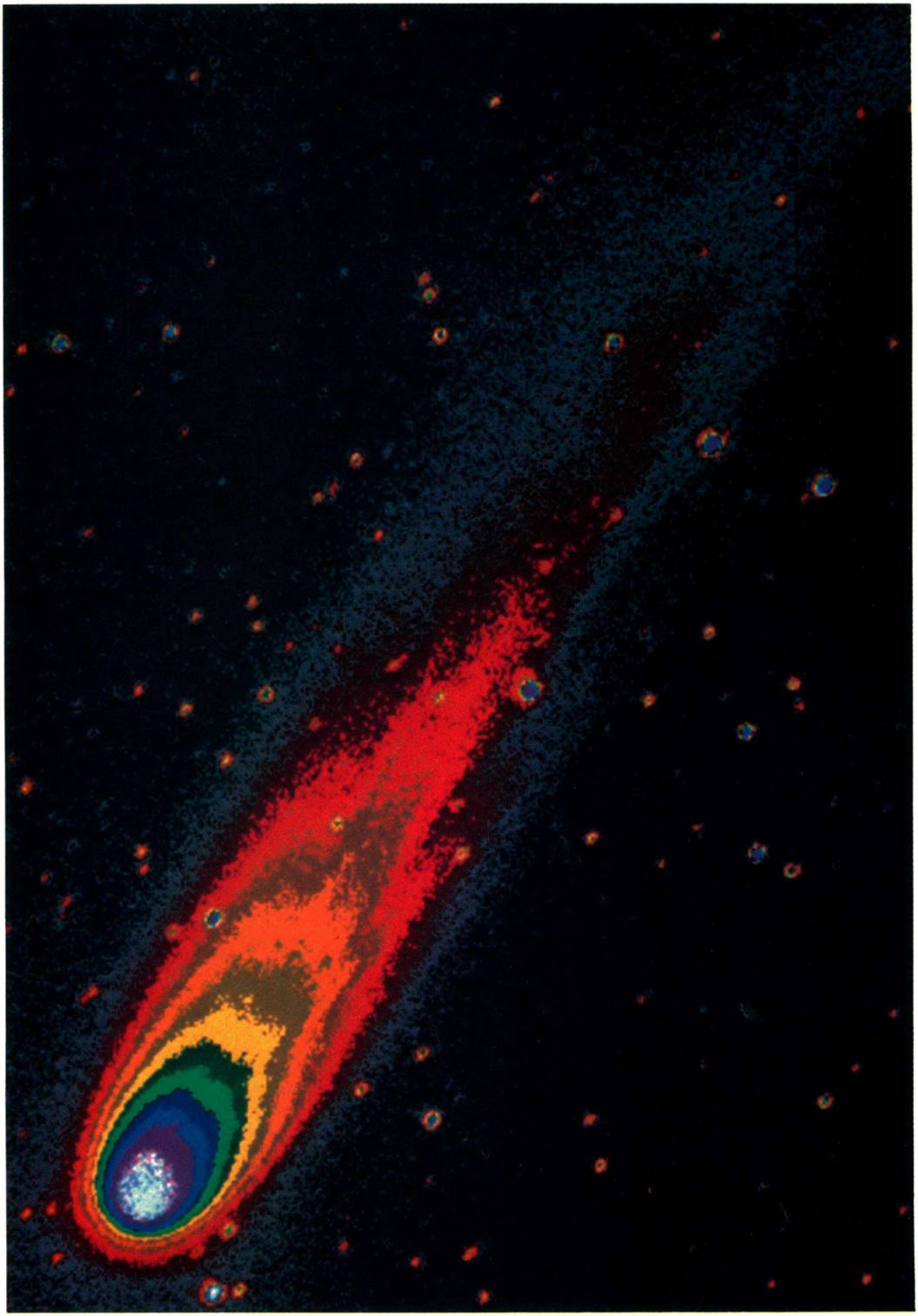
The region down to about 100,000 kilometers from the nucleus is known as the "intermediate region." From the bow wave to 550,000 kilometers, this region is characterized by large density and temperature fluctuations, with the average density increasing and the average temperature remaining constant. The inner part of this region is marked by less fluctuation in density and temperature with the average value of each decreasing slightly.

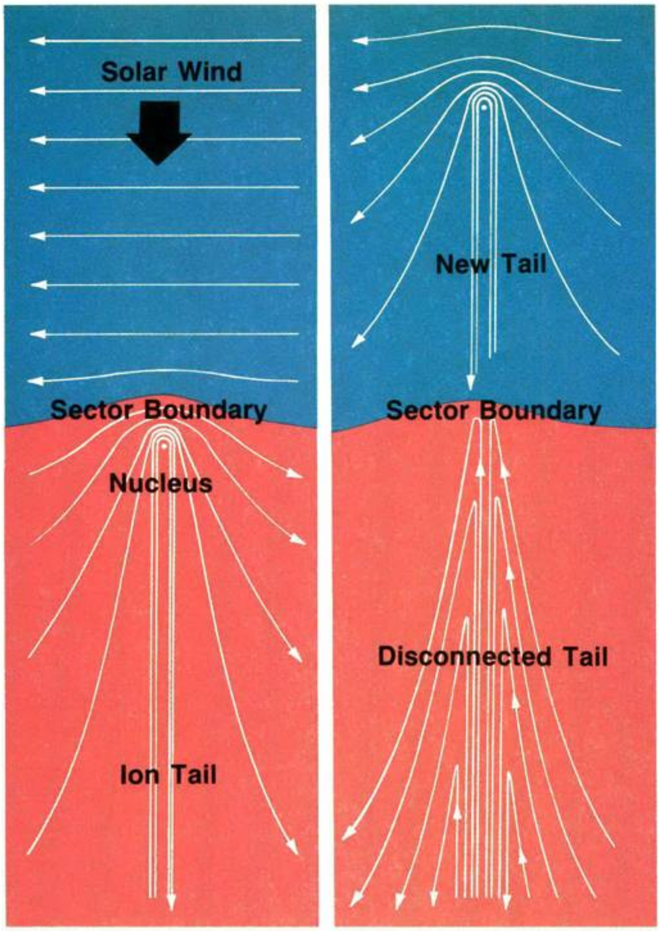
From there to the contact surface — the boundary beyond which the solar wind cannot penetrate — lies the "inner region." This region is marked by the largest changes of all in electron density and temperature.

The solar wind does not move unimpeded through the comet's atmosphere. Because many of the atoms in the coma are ionized, they are not free to travel across the magnetic field lines carried by the solar wind, and so are caught up in the flow of the solar wind. Because ions are continually produced in the coma, the wind is forced to carry more material along with it and must therefore slow to conserve momentum. The process continues as more ions are added and the flow slows down until the inward pressure exerted by the solar wind is balanced by the outward pressure from the gases of the coma. This boundary is known as the contact surface. Since the solar wind cannot penetrate beyond this surface, a magnetic cavity is created that contains no magnetic field. The width of this cavity was 8,500 kilometers along Giotto's trajectory. Neither of the VeGa spacecraft flew inside the contact surface.

Off to the sides of the comet (as it would be viewed from the Sun) the number of ions trapped in the magnetic field drops substantially, allowing the solar wind to pass by without much difficulty. Thus the magnetic field lines become draped around the comet and channel the coma ions into an ion tail.

Spectroscopic studies of Comet Halley's ion tail indicate differences between pre- and post-perihelion composition. On its inbound journey, Halley's tail shone brightest in the light of H_2O^+, while on its outward trek CO^+ was dominant. The result was not totally

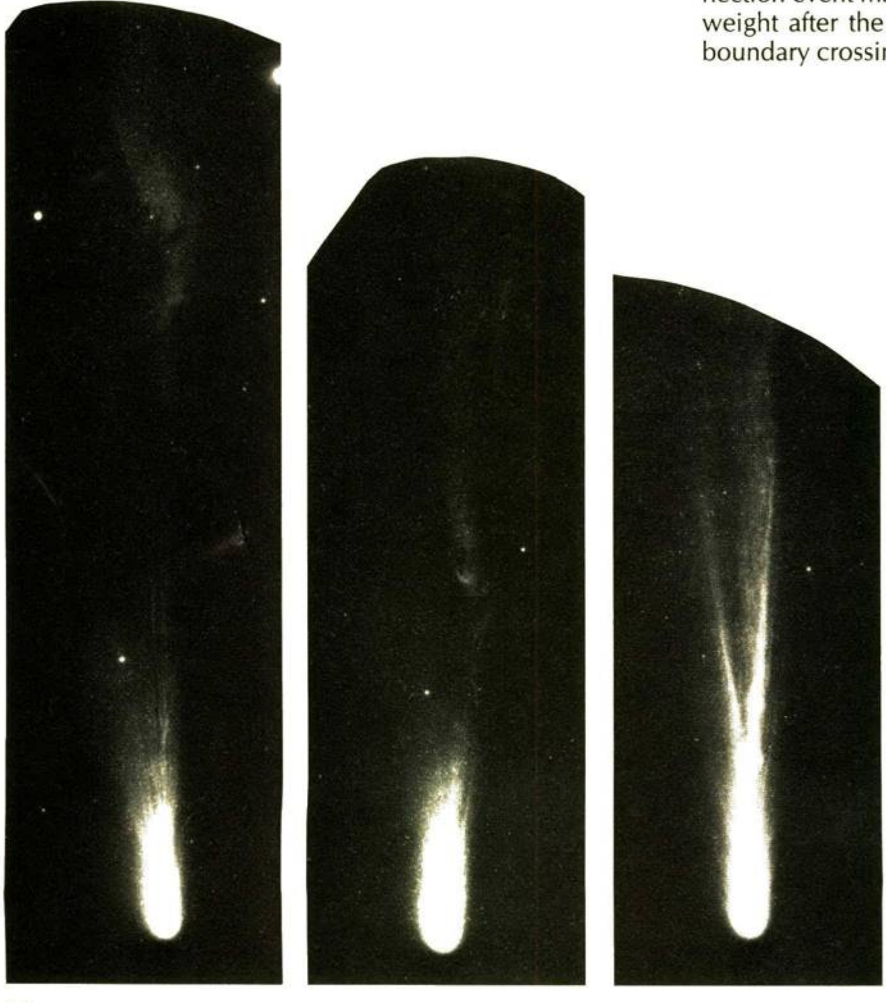




John Brandt and Malcolm Niedner of NASA's Goddard Space Flight Center propose that tail disconnection events occur when a comet encounters a perpendicular sector boundary. Such a boundary marks the division between regions, or sectors, in the solar magnetic field having opposite polarity. In the left diagram, magnetic field lines in one sector (red area) have become draped around the comet and are channeling captured ions from the coma into an ion tail. As the new sector (blue area) reaches the nucleus, the old field lines are cut and detach from the comet (right diagram). The disconnected tail holds on to the ions previously captured as it moves away from the nucleus, while the new sector's magnetic field lines capture fresh ions and begin to form a new tail.

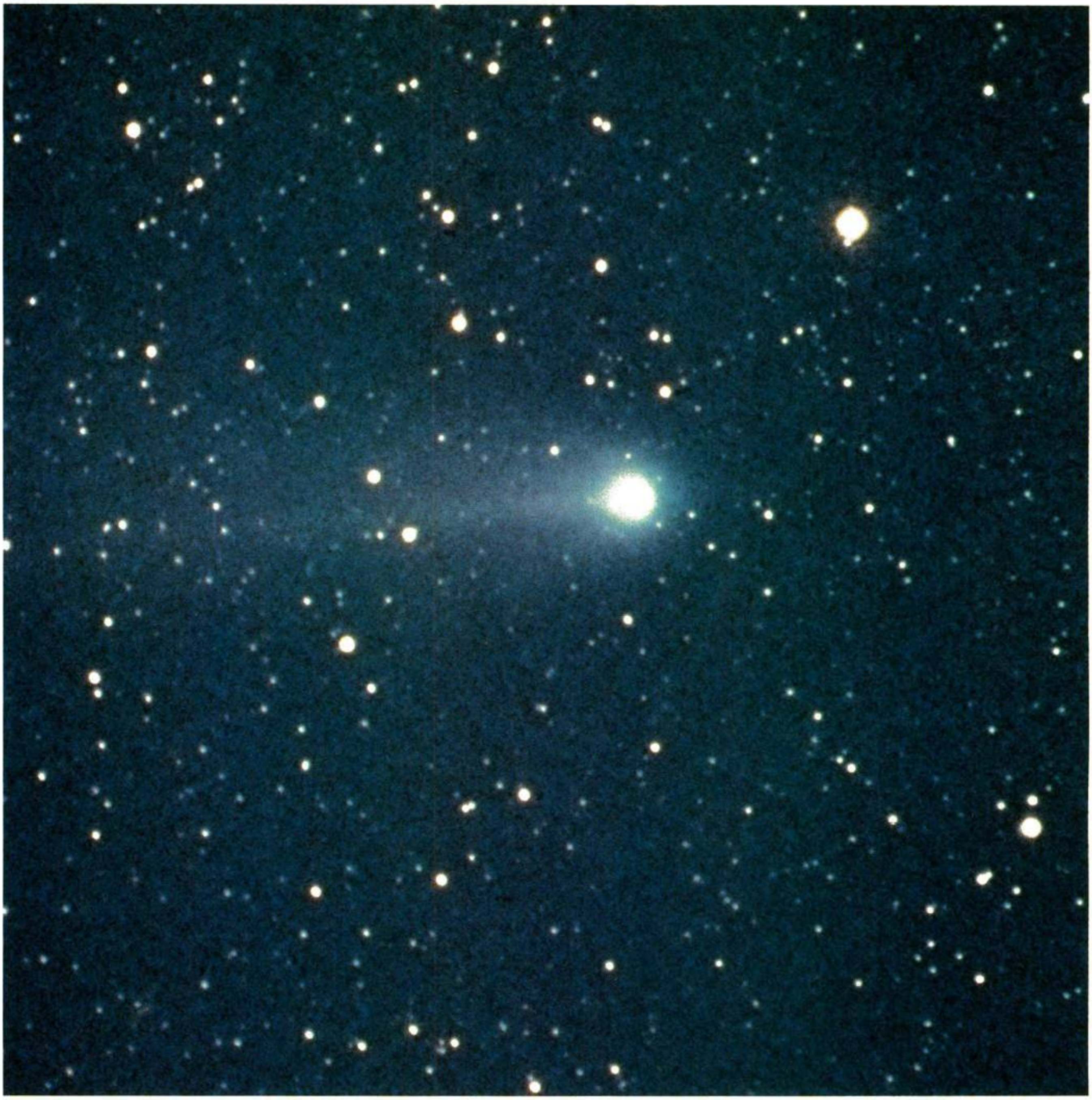
unexpected and is believed to result from material coming from different levels of the nucleus. After perihelion the material sublimating from the comet comes from several meters deeper in the nucleus, a level from which volatile gases such as CO may not have previously escaped.

Observations of the solar wind by the Sakigake spacecraft may shed some light on the process of tail disconnections. During its closest approach, from March 10 to 12, the probe detected a change in the polarity of the magnetic field, indicating it had crossed a sector boundary in the solar wind. (The solar magnetic field, carried by the solar wind, consists of four "sectors" of alternating polarity; the border between any two such sectors is called a sector boundary.) The crossing of such a sector boundary has been proposed as the cause of disconnection events, yet no such event was seen from Earth in the following days. The Japanese scientists propose that if the boundary crossed is nearly parallel to the comet's tail, as this one was, then a distinct disconnection event may not occur. The proposal gained added weight after the probe detected a nearly perpendicular boundary crossing on March 18/19 that was followed on



Right: Five days after closest approach to Earth, Comet Halley passed near the giant radio galaxy NGC-5128, also known as Centaurus A. Taken by Arturo Gomez on April 15 with the Curtis Schmidt telescope at Cerro Tololo, this photo shows a wealth of structure in Halley's ion tail. Rays, streamers, and kinks can be seen as material is blown away from the comet's coma by the solar wind. Halley's 70°, fan-shaped dust tail can also be seen. National Optical Astronomy Observatories photo.

Left: The spectacular disconnection event of March 20/21, 1986, was photographed with the 18-inch Schmidt camera on Palomar Mountain. Taken at one-day intervals from March 20 to 22 (right to left), these photos show the ion tail as it detaches and moves away from the comet's coma at the speed of the solar wind. These events may result from the crossing of a perpendicular "sector boundary" (see diagram above), one of which was observed by the Japanese comet probe Sakigake on March 18/19. The March 22 photo shows the start of a new ion tail. Copyright 1986, California institute of Technology.



Robert Schmidt took this photo with the Naval Observatory's comet camera on May 2, 1986. A narrow ion tail can be seen stretching over 6° from the comet's nucleus. The bright, reddish star to the upper right of Halley is Nu Hydrae. U.S. Naval Observatory photo.

March 20/21 with a spectacular disconnection event.

However, since none of the space probes passed on the tail side of the nucleus, most of our knowledge on tail structures will come from Earth-based images, taken mostly with big Schmidt cameras. The analysis of rays, streamers, kinks, and disconnection events will come when the images are correlated to measurements of the solar wind taken over the entire apparition. This is done to ensure that an observed tail feature regularly results from a specific change in the solar wind and is not an isolated, random occurrence. With past comets only isolated instances were recorded, making a cause and effect relationship difficult to discern. Once such an analysis is complete, researchers will have a much better idea just what affect irregularities and sector boundaries in the solar wind have on a comet's gas tail.

Learning about Comet Halley had nothing to do with the hoopla and hype. The process began with the recognition of an impending astronomical event and continued with painstaking planning to ensure the cooperation of astronomers around the world. The true story of Comet Halley is one of contained scientific excitement, of space missions proposed and budget requests denied, of long nights observing in cold observatory domes, of years spent building instruments to collect five minutes worth of data, of spacecraft telemetry streaming back, and weeks, months, and even years of data analysis.

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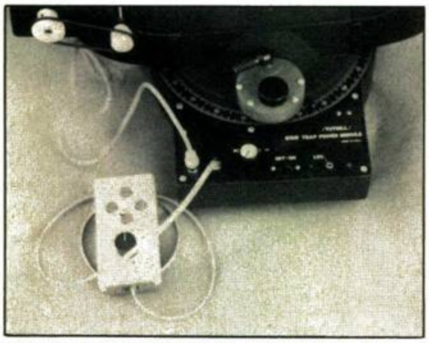

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ASTRONOMY
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On The Road With Comet Halley

Illustrations by Todd Graveline

VIRGINIA

There it was, Halley's Comet, its tail arcing westward away from where the Sun should be. Thousands of stars gleamed in the morning sky as if to greet this once-in-a-lifetime visitor from afar. I stood marveling at this spectacular glowing sight. . . .

My alarm clock went off. Reality set in. Too bad it was only a dream.

I awoke rubbing my eyes and squinting at the digital numbers on my clock radio — 4:25 a.m. Great, I thought. It was March 18, 1986, and I figured by what ASTRONOMY and other astronomical publications were saying that Halley would be something like the dream I had only minutes ago.

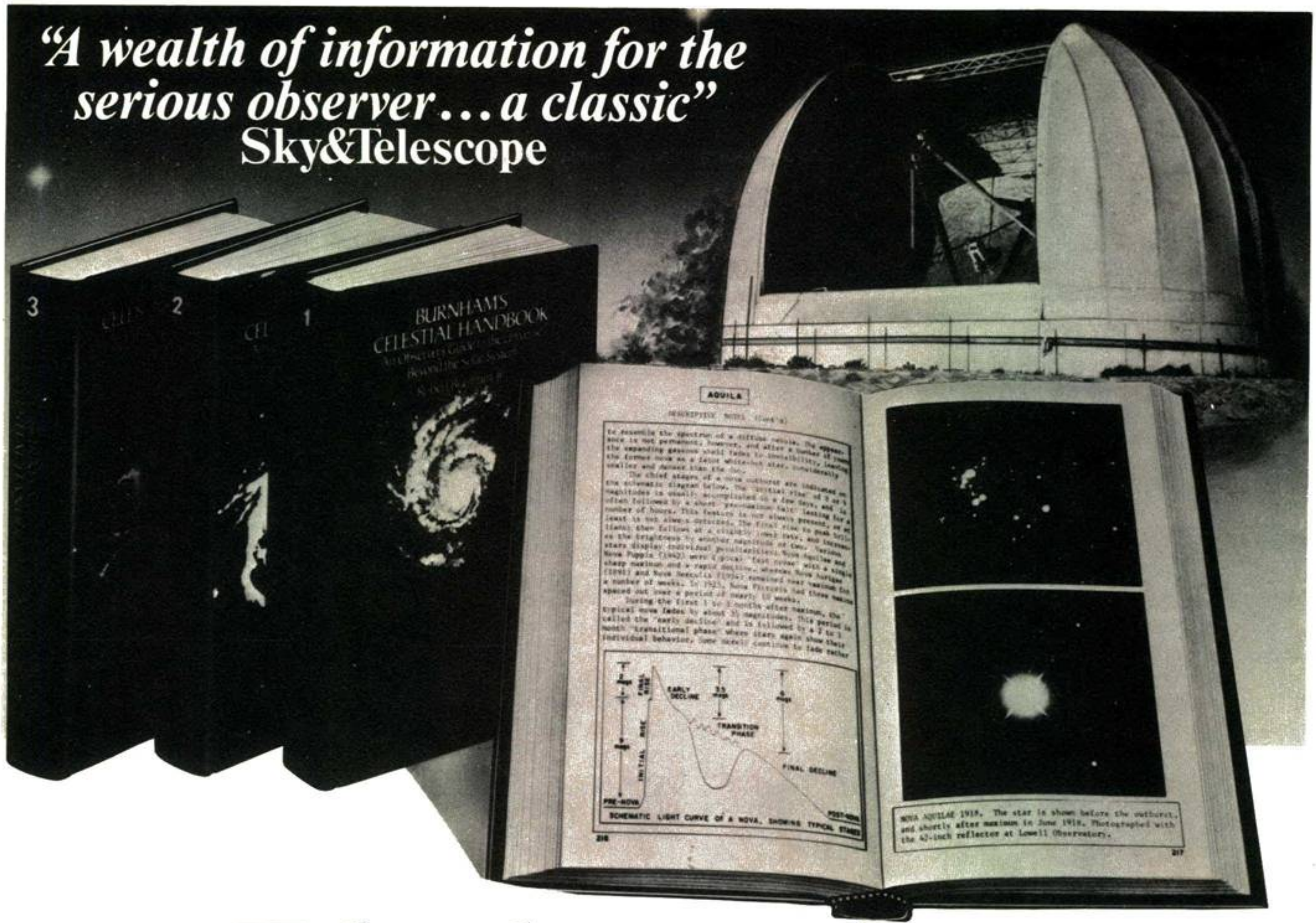
I ventured outside into the chilly air, the 11x80 binoculars around my neck, and immediately looked up. It was worse than I had expected. Scorpius was barely visible and Sagittarius was not visible at all. Light pollution was all over the sky, especially where Halley should have been in the southeast.

I raised the binoculars to my eyes and looked in the general vicinity of the comet — nothing. Man's curse of artificial lighting was preventing me from seeing one of nature's glories. I ran around like it was the end of the world, trying to avoid the unavoidable light pollution that was staring me in the face. I knew then I had lost this battle.

I walked inside and looked at my mother who was laboring at her morning chores in the dark house. She saw the disappointment on my face and frowned. I put my binoculars back on the table and took off my jacket.

"Wait a minute!" I thought. "The streetlights were blinking off when I was walking inside. Surely other *manmade lights would* be off by now, too." It was 5:13 a.m. I had to race the oncoming dawn to see the comet.

Outside, all the manmade lights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were off, but dawn was lighting up the sky ever so slightly. However, I could see Sagittarius a lot better than before. I raised my binoculars and looked to the east of the Teapot — there it was! It was white and diffuse and I could even make out a slight tail pointing away from where the Sun would soon rise. I had only a minute or two to behold this magnificent sight.

It was over as quickly as it began. The light of dawn erased the comet from the grasp of my binoculars, but not from my memory.

As I walked inside, my mother was still cleaning. She looked at me and smiled.

David Abbou
Alexandria, VA

TOBAGO

As April approached, amateur astronomers worldwide were finalizing plans for viewing Comet Halley during the prime period of its outward leg. Some members of the Rockland Astronomy Club headed to Australia, where they planned to observe the comet from Ayers Rock at a net cost of $145 an hour. That was too rich for my blood, so some of us opted for the southernmost island in the Caribbean with dark skies — Tobago. Located at 11 degrees north latitude, it would provide decent views of the southern skies at under $10 per observing hour.

The trip down to Tobago was uneventful. The customs agent in Trinidad eyed our five telescope trunks, an equal number of eyepiece cases, and assorted boxes containing tripods, wedges, and folding stools. We were armed with enough red flashlights to outfit a major Caribbean island. After a fifteen-minute conversation about the comet, he realized we were definitely not the smuggler type and waved us through.

On our first night there I looked up and could immediately identify only Orion and the Big Dipper. Regulus was dead overhead and the Sickle was upside down. Orientation took more than just a few minutes.

"O.K. guys, enough gaping at the skies; let's get polar aligned." Polaris was way down there in the early evening haze that hangs over the ocean for a few hours after sunset.

The group attacked the long-awaited southern skies. Each one of us went for what we thought would be our personal favorite. Within seconds all five scopes were *trained* on Omega Centauri. "Wait until you see this baby using a 7mm Nagler. It's awesome!" After twenty minutes or so someone realized that NGC-5128 was only a hop and a skip away, and a whole new round of statements about incredibleness began.

We made a pact: Even though Scorpius was well up, no one would home-in on the comet until it was at least 20° above the horizon. Of course, we couldn't help but notice there was a naked-eye object near Theta Scorpii looking all the world like Omega Centauri.

Then disaster struck! A nasty looking cloud appeared in the southeast. We had been warned that rapid weather changes were common in the tropics. Pacts were forgotten; everyone went for Halley.

What a coma! There was fumbling for telecompressors and wide-field eyepieces. Oh yes! There was a stubby tail too. Time passed and Joe Folmer noted that our nasty cloud hadn't moved too far. In an instant we realized what Joe already knew: that obnoxious object polluting the sky was the Sagittarius Star Cloud!

Michael T. Kitt
Bronxville, NY

AUSTRALIA

We came in search of Halley's Comet, but we were ready for an adventure, whether or not the comet complied. As it turned out, that was a very appropriate attitude. The comet was interesting, but it was dim and elusive.

The first night in Sydney, bathed in blue neon lights on the roof of the Koala Inn, I saw Leo upside down in the north and watched Mars and Saturn rise on the wrong side of the sky. Halley was next to Scorpius, though the neon light obscured the comet's tail.

The Worcester [Mass.] Science Center had chosen to lead a group of thirty hearty members to Australia because of the clear skies promised by the Outback. We were not disappointed. It was clear on thirteen out of fifteen nights! The stars gave the illusion, as one member put it, of being in a planetarium with stars visible down to the horizon. There were numerous clusters that were easy naked-eye objects and were spectacular in binoculars and the telescope. The Milky Way was quite awesome. Every night we managed to see something new.

Having an 8-inch SCT along certainly helped. We never did get over Omega Centauri filling our field of view with hundreds of stars. The Tarantula Nebula in the heart of the Large Magellanic Cloud was also spectacular. The nebulosity around Eta Carinae surpassed the Orion Nebula. Many people in our group had never looked through a telescope before, but I think they could tell from our unbridled enthusiasm just how special those skies really were.

There was a partial solar eclipse on April 11, which we dutifully observed with binocular projections onto cardboard and pinhole projections made by our hands and the leaves of trees and bushes.

Setting up the star tracker on the south celestial pole for photography was a trying task. I kept looking from the star chart to the sky and back again to the chart. But I was rewarded with a fine view of a slow shooting star that I followed with the binoculars. I watched it flare slightly and then fade, disappearing in a trail of faint gray smoke. Watching this was similar to the feeling of that first hill on a roller coaster, with my heart in my throat.

As for the comet, well, it wasn't all that bad. In binoculars its tail was about 8° long at its best and very spread out, like a fan, over an angle of 90 degrees. One edge of the fan was bright; this was probably the blue gas tail pointing directly away from the Sun. I attempted to use an orange and a blue filter on my binoculars for a blink-test comparison of the two tails, but the comet wasn't bright enough for this experiment.

The comet did pass near Omega Centauri. It was fun comparing Omega Centauri and Halley in brightness and size. For a brief while the comet was the brighter of the two, and they were about the same size through binoculars. Many Australians were calling observatories asking about the two comets in the sky.

Joel Gendler
Worcester, MA

EQUADOR

My interest in astronomy started when I was in the seventh grade. One of the first objects I learned about was, of course, Halley's Comet. From that time on I have greatly looked forward to seeing this famous comet.

In April 1986 I led a group of curious Halley enthusiasts on a trip to South America. There was not a single amateur astronomer in the group. My trip proved to be more of a roving classroom than a scientific expedition. The emphasis changed from serious observing and photography to the joy of discovery, for both the group and the local people we encountered. I had initially planned to show everyone the comet and then, once everyone had their fill of that, move on to other objects in the night sky.

While looking at Halley, one of the group members noticed another "comet" near Halley. This "other comet" was, of course, the globular cluster Omega Centauri. In honor of the "discoverer," Herb Sabel, we referred to Omega Centauri as "Herb's Comet."

For the local people, the thrill of discovery happened every time I set

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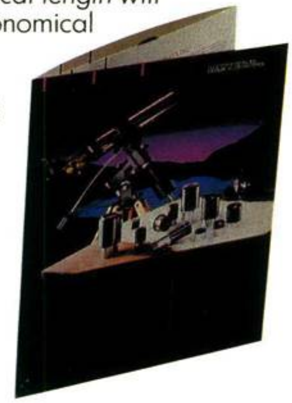

Tele Vue 20 DEXTER PLAZA, PEARL RIVER, NY 10965 (914) 735-4044 up my telescope. The most notable observing period was from the roof of the Inter-Continental Hotel in Quito, Equador. Although our observing site was in the city, the sky was dark enough to see the comet with the naked eye. During our observing session several hotel employees made their way to the roof for a look at Halley. The number of employees increased every minute. Before too long, it seemed as though the entire staff was on the roof looking at the comet. I learned later that the front desk had been closed temporarily so that all the employees could see Halley.

The local people enjoyed the comet more than those of us who had traveled halfway around the world to see it. Although the language barrier was severe, the excitement seemed to penetrate that barrier without any problem. We were able to show them the comet and hear the exclamation of joy as they saw it for the first time. All this without the ability to communicate in a common language. It seemed as though Halley's Comet, if not astronomy itself, had become a universal language.

Mark J. Coco
Redondo Beach, CA

ARGENTINA

During the second week of April 1986 I had the pleasure of visiting friends in Argentina and traveling to the town of Barreal in San Juan province to visit the Felix Aguilar Observatory at Leoncito, there to observe Halley's Comet. From the observatory the high Cordilleras of the Andes Mountains loom to the west, dominated by the mighty Aconcagua, the highest mountain in the Western Hemisphere.

Observing conditions at these sites were superb. There was an unbelievable clarity to the sky there day *and* night. According to the astronomers at the observatory, there are 320 days of "useful" seeing yearly, which they define as six hours nightly without clouds, and 210 photometric nights, so-called because of the especially stable seeing.

The observatory, in operation since 1965, is currently operated by Yale and San Juan Universities. The initial mission and fundamental program at El Leoncito is to study the proper motion of the stars in the Southern Hemisphere from the South Pole to 25° north latitude.

The programs carried out by San Juan University include a study of asteroids, especially the fainter ones whose orbits and positions are not well known. The International Astronomical Union has credited the discovery of forty-two asteroids to Leoncito.

Another program of more current interest involves following comets and determining their positions. Five comets have been credited by the IAU to Leoncito. A group from the Max Planck Institute in Munich was at the observatory making observations of Halley's Comet and its interaction with the solar wind.

On our first night's visit to the observatory we dimmed our headlights some distance from the site, as requested, then parked and walked the remaining thirty yards using flashlights. The glow of red and blue lights from the electronic equipment, the images of the comet on the several small TV monitors associated with each telescope, and the glittering southern night sky had a powerful and awe-inspiring effect.

We were told that the comet had essentially lost its tail because of its orientation in space relative to Earth. It was, however, fairly easy to spot, although the brilliance of the Milky Way, the Southern Cross, and the aptly described "ghostly" Magellanic Clouds upstaged the comet for me.

We finally left the observatory, tired but thrilled, at 4 a.m. The following night we drove a few miles from our inn down a dark country lane. Once again seeing conditions were excellent. With some effort we could identify a few of the unfamiliar constellations, such as Norma and Lupus, in which we saw the comet. The glow in the eastern sky as Sagittarius and its surrounding star clouds climbed into view, accompanied by ruddy Mars, was breathtaking.

Stephen Krauss
Knoxville, TN

PERU

We hadn't been in Lima, Peru, twenty-four hours before we learned of the problem: the entire country was covered with clouds. Some Americans told us that it had rained daily during their week in Cusco and environs, precisely the area chosen to do our serious Halley and southern constellation viewing from.

Could it be possible to spend eighteen days in Peru and miss the comet entirely?

The picture that persisted was of an impenetrable blanket of cumulus covering all of Peru with thousands of American amateur astronomers running all over the place trying to pierce the stygian murk.

Incas 1 — Halley Watchers 0.

Still, after enjoying Lima we flew to Cusco, a lovely Indian town at 11,200 feet elevation, allowing the necessary several days to get used to the oxygen-poor heights while the Moon interfered with Halley.

Among our plans was a visit to Machu Picchu, the legendary "lost city of the Incas." We left during mid-week — a relatively slack time. The three half-full train cars were just beginning to shake down their riders when an over-zealous engineer's foot got too heavy and the entire train derailed. The first two cars fell over and scraped along a dirt embankment for some distance. Eighteen people were injured, track was twisted, crossties cut in half and uprooted.

Incas 2 — Halley Watchers 0.

But the train to Machu Picchu was running again the very next morning with several of the injured on board for another try. We all goodnaturedly cheered when the site of the previous day's accident was passed.

That evening, after returning from Machu Picchu, the inevitable clouds billowing over Cusco held off and we got our first-ever view of the Large Magellanic Cloud. It was fast setting in the west, but the galaxy itself, looking indeed very much like a cloud in binoculars, was clearly outlined.

Incas 2 — Magellanic Cloud Watchers 1.

A good omen it was, as later that same night we awakened to still clear skies and were able to view "la cometa Halley" from the inner courtyard of our hotel. The sky conditions weren't the best and city lights interfered some, but it was a great thrill to see the comet an awesome 60° above the southern horizon. It was small though fat and bold without much of a tail.

Incas 2 — Halley Watchers 2.

So the game wasn't over, but this unexpected night of fairly good viewing puzzled us. Should we stay in Cusco or head for Arequipa?

While munching snacks off the ubiquitous carts and portable ovens of Inca descendants, we pondered our problem the next afternoon, unaware that the power known by that long-departed empire was about to change our astronomical venture into a geology lesson.

At 3:16 p.m., as we strolled by one corner of the main square of Cusco, the ground began shaking and deep rumblings were heard and then felt

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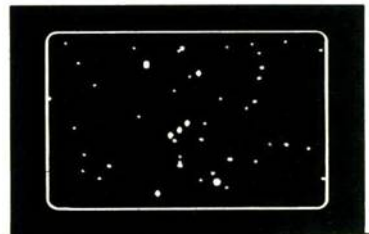

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along with the sounds of falling glass and concrete. Earthquake! We ran for the central plaza as the terrifying tremors slowly subsided. The papers later reported 5.8 on the Richter scale.

Incas 3 — Halley Watchers 2.

Rumors were spinning: northern Chile was devastated, Arequipa was flattened. Where could we go? These were unfounded rumors, of course. And the clincher for going to Arequipa was the set-up provided there by the A.P.A. (Asociacion Peruana de Astronomia, the Peruvian Astronomical Association). Nightly buses left at 8, 10, 12, and 2 for a viewing site some miles outside of town. For $10 per person, one not only got transportation but all-night snacks of ham and cheese sandwiches on Peruvian rolls, marvelous pastries, and all the very strong Peruvian coffee or coca tea one wanted.

There was a 14-inch Schmidt-Cassegrain telescope (given to the A.P.A. by the Astronomical League) and plenty of room for one's own equipment plus complete toilet facilities and couches on which to rest between viewing sessions, all illuminated by soft red lights and the murmur of contented amateur astronomers comparing notes.

The sites themselves were hardly less romantic than Machu Picchu. One was an old mill, a tourist attraction by day, its rippling waters providing a gentle background of sound. The other was even more gothic — an eighteenth-century castle. Leaning back in front of the fireplace with a coat of armor hanging above, one could almost see the ghost of Edmund Halley going outside to take one more look at his numinous namesake.

The weather held for us, and we got one good night and one great night of long, leisurely viewing. Thanks to the A.P.A., and a bit of luck, the score ended:

Incas 3 — Halley Watchers 3.

John and Stephanie Mood
San Diego, CA

CHILE

By the summer of 1985 Comet Halley had brightened enough to tease enthusiastic amateurs at dark locations. From Stellafane's Breezy Hill in Vermont I glimpsed the faint coma in the pre-dawn sky when it was still a challenge for 16-inch telescopes. By January, the comet's tail was easily seen from dark locations, and predictions of Halley's post-perihelion performance became rather suspect. Would it brighten after its solar encounter and put on the "Greatest Show Above Earth," or would it fizzle in the tradition of Comet Kohoutek?

The historical significance of this celestial vagabond was obvious, and it seemed only logical that I position myself in one of the "best seats in the house" to enjoy the close encounter.

After considering many locations, I decided to travel with a group of astronomers from NASA to Chile, the home of some of the world's finest observatories. The location of our front row seats was about 60 kilometers into the Atacama desert, east of the mining port of Antofagasta. The Atacama is probably one of the driest deserts in the world, with some locations never reporting measurable rainfall. Weather would not be a factor here, or so I thought.

With a large footlocker and a 5-inch telescope in tow, I arrived ready for the show to begin. We had reservations for "six performances" of Halley and I had pre-planned strategies to maximize every minute of each night.

On the first night a specific site in the Atacama was selected and I examined the skies through binoculars. Halley was there but it had some stiff competition with the southern Milky Way. Canopus, the Southern Cross, and the Sagittarius Star Clouds shown with the same intensity as the long exposures of the Milky Way that I had seen in my childhood textbooks. This is hardly an exaggeration. The sky must be seen from the Atacama to fully appreciate a dark site.

Halley was doing fine. Its tail exceeded 10° in binoculars but thinned out in the general glow of the Milky Way. I estimated its coma to be 1° in diameter and its brightness to be about 2.5 magnitude.

Our Chilean guide called me "Chief Big Night Eyes" since I spent most of my time peering through my 7x50 binoculars and C-5 telescope. He graciously provided coffee and refreshments for the NASA group, which helped us endure the cool desert environment.

The nights were dark and the sky clear until the "Comanchaca", or Pacific fog, rolled in at about 2 a.m. Prior to Comanchaca's arrival the temperatures had gradually fallen to the dew point and condensed water had coated all optical surfaces. Obviously weather was a factor, even in the driest of deserts. To keep the optics cleared I resorted to holding the C-5 close to a propane stove to warm the corrector and secondary.

The Southern Hemisphere was indeed the front row. From downtown Santiago at midnight I could see Halley with the naked eye (although without a tail) at about 60° elevation. I thought about home — the view from Connecticut would put the comet within 5° of the horizon. We do live on a sphere!

Each night while returning from the Atacama I could see cars parked at the roadside and families peering high into the southern sky. In the remote town of Chiu-Chiu in the Andean foothills, I spoke broken Spanish to an elderly man who noticed my Halley T-shirt. I asked him if he had seen the comet. He smiled and pointed high to the south as though motioning to an old friend.

Philip L. Dombrowski
Glastonbury, CT

NEW ZEALAND

Dunedin is a small city on the eastern coast of the South Island of New Zealand, which lies 45.5 degrees south of the equator and is the home of the Dunedin Astronomical Society.

For the Society, Halley's Comet holds particular interest because it was for the last appearance of the comet that the Society was formed. Later on, the Beverly Begg Observatory was built, from which the Society now operates.

The members of the Society first photographed the comet in August 1985 and have been keeping a watchful eye on it since then, losing it for almost two months between January 4 and February 20 this year.

After its reappearance from behind the Sun, the comet's apparent size grew quickly throughout the following weeks, being about one to one-and-one-half magnitudes brighter than expected with a tail length well within predicted margins (about 10°). Excitement and interest grew, and as the comet slipped into the glare of the waxing Moon we started publicizing our expectations that April "evening" viewing could well be spectacular.

Easter Monday was awaited with anticipation. The rate of bookings for tourist parties and public groups wishing to visit the observatory increased steadily.

A joint venture we had entered into with the "Otago Excursion Train Trust" — The Halley Express, a vintage train ride to a dark sky location 50 miles from the city — quickly sold out and extra trips had to be arranged.

The skies darkened with the waning of the Moon. The comet was again clearly visible and the coma had grown considerably, but where was our 15° tail growing to over 30° in early April? Our photos managed to dredge out 4°, which slipped to about 2° with the merest suggestion of an antitail on April 11.

The coma increased still more owing to the closer proximity of the comet and filled and spilled from a half-degree field. However, the central condensation of the coma weakened, which suggested that outgassing activity around the nucleus was subsiding.

Nonetheless, the spirit and interest of our membership did not subside, if anything it increased owing to the unpredictability of the apparition and

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the prospect of seeing an antitail.

On the other hand, the event had been so keenly awaited by a public anticipating a 100°-plus tail that it was nearly impossible to explain to them night after night (at the rate of about 1,500 times a night) that "what you see — 'that dim fuzzy blob' — is what you get."

Owen Lamb
Dunedin, New Zealand

AUSTRALIA

Being an amateur astronomer and wanting to get the best possible view of Halley's Comet, I decided to take a trip to Australia this past April. But this is not my reason for writing this article. Oh yes, I did see Halley and the rest of the beautiful southern sky. But for a couple of days I was one of the fortunate forty-two people who shared a bus and tour facilities with Patrick Moore, the famed British astronomer.

I knew before the trip got underway that we would get a chance to hear Dr. Moore give a talk on the comet, but that's as far as I thought it would go. He would give a lecture, sign some autographs, and then be on his way.

That evening, after a full day of shopping and sightseeing, we returned to our hotel early to be assured of a good seat at Dr. Moore's lecture. He's a delightful speaker. His command of astronomical facts and figures is truly astronomical, all blended with personal experiences and subtle nuances of humor. He speaks with flair and style, arm akimbo and monacle dangling about his neck ready to be applied to eye to catch a detail of a slide.

There were rumors that night that Dr. Moore would be on one of the tour buses the next day. I thought, "How ridiculous that they would even consider that anyone as famous as Patrick Moore would travel overland in a coach."

You can imagine how surprised I was when I boarded my bus the next morning to find Patrick Moore taking attendance! Here we all were on the bus, Dr. Moore wearing an olive green shirt adorned with maroon flowers, checking off our names as he called roll.

Our first destination was Parkes Radio Observatory, located a couple of hundred miles from Sydney. At one point Dr. Moore got on the public address system to ask if we would like him to give a brief history of the observatory and radio astronomy in general. He asked for a show of hands. As far as I could see it was unanimous. Moore talked for thirty minutes and rattled off dates, figures, and names of important events and people who played a part in radio astronomy.

One evening in a field adjacent to our motel, a group of us were doing some observing. All of a sudden I heard Patrick Moore pointing out features of the southern sky to one of our group, something he clearly did not have to be doing, especially after the tiring day he had put in with us. He modestly said that this helped him to refresh his memory of the southern sky.

Our next stop was Siding Spring Observatory. Dr. Moore said that he had been to just about every major observatory in the world, but that this was definitely his favorite. Once again, as was the case at Parkes, we were given special treatment. We got to tour most of the facility and meet several of the astronomers working there.

That evening Dr. Moore once again volunteered to give everybody a personal tour of the southern sky.

The morning after our visit to Siding Spring, we were getting ready to board our bus. Patrick Moore would not be continuing with us, but he was still out there to wish us all the best. The last time I saw him he was on the curb waving goodbye.

Robert A. Jones
Worcester, MA

TEXAS STAR PARTY

In early May, my wife and I drove to the Texas Star Party outside Fort Davis, hoping someone would let us look through a large telescope for our last glimpse of the swiftly fleeing comet. We spent two nights camping in Big Bend National Park before going to the Star Party, but could not find the comet through binoculars.

When we arrived at the Prude Ranch on May 6, we got our first look at Comet Halley since March. It did not impress us. The head shone faintly and the tail was a small fan trailing dimly above it.

Wednesday night was not better. Halley was a dim patch in a 10-inch telescope. Ah, but Thursday night brought a dramatic change. The comet brightened and the tail tightened into a beautiful, flowing cape, spreading 5° or 6° to the southeast.

My wife and I walked around the ranch comparing views provided by different telescopes. When the comet sank behind the mountains we were satisfied that we had gotten the best look at it that anyone in the world got that night.

Friday brought another spectacular show. Lightning flashes in the east and meteors from all around highlighted another beautiful view of Halley.
I thought back on my childhood dreams of Halley as I walked up to a 7-inch refractor that revealed exquisite detail in the comet's tail. A 20-inch Dobsonian brought the nucleus into clear view, destroying the night vision in my right eye for twenty minutes. That sight alone was worth the drive to Fort Davis.

Darron Spohn
Kerrville, TX

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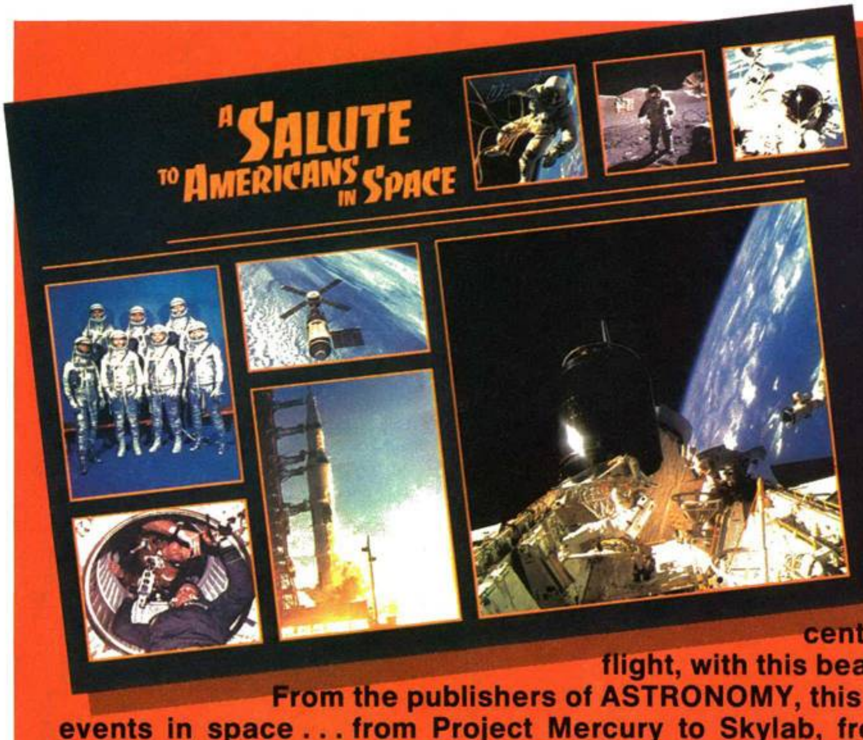

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Teach your old

When you've been building 8-inch catadioptrics for fifteen years, you learn a trick or two about making them better.

Better, in this case, happens to be a completely new line of accessories.

Which let your Celestron "cat," whatever its age, deliver a viewing experience unlike any other 8-inch telescope.

TEACH YOUR CAT TO READOUT.

Trac-Star, our new, state-of-the-art electronic digital setting circles, makes finding deep sky objects easy.

Fix on a celestial object you know the coordinates of. Set the RA and DEC. A photo-sensor encoder "reads" your position as you sweep the sky. The coordinates your C8 is pointing toward are then read out by the LEDs on the control box display.

All this high technology costs less than you think. And it can be retrofitted to almost any C8.

IMPROVE YOUR CAT'S LOOKS.

Celestron cats have always had great oculars. But with the addition of our new *Wide Star* eyepiece, you'll get an even better look at the sky.

Wide Star is a combination of a new, high-performance (yet inexpensive) 2-inch diagonal and a new 2-inch ocular. Images are tack-sharp and of ultra-high contrast. The 50mm focal length and multicoated Plossl design gives 40X magnification. Eye relief is excellent.

With a 44° field of view and a 38mm field stop, *Wide Star* will let you see even large (though faint) objects easily.

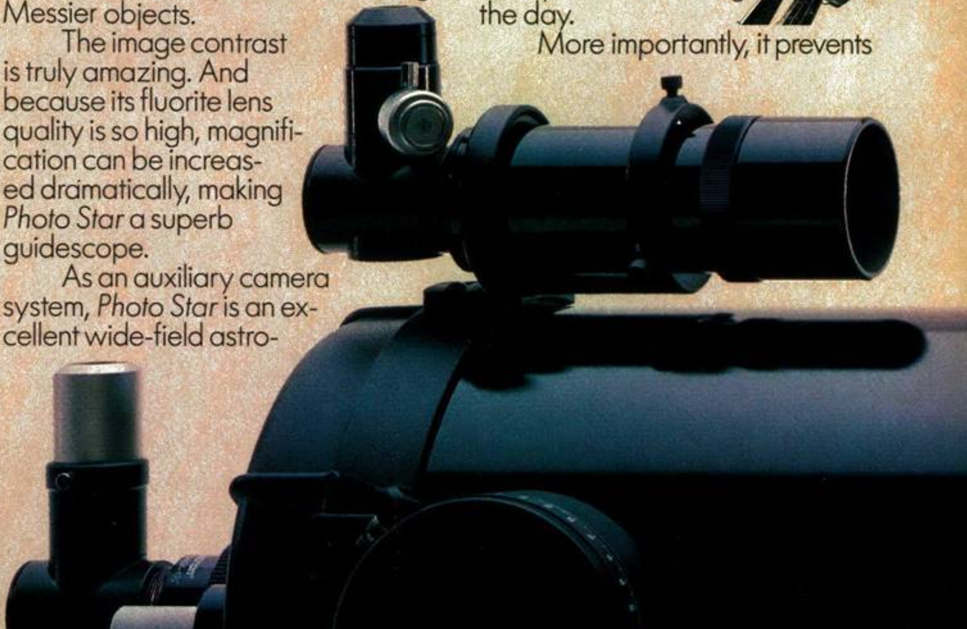
FOR THE CAT THAT HAS EVERYTHING.

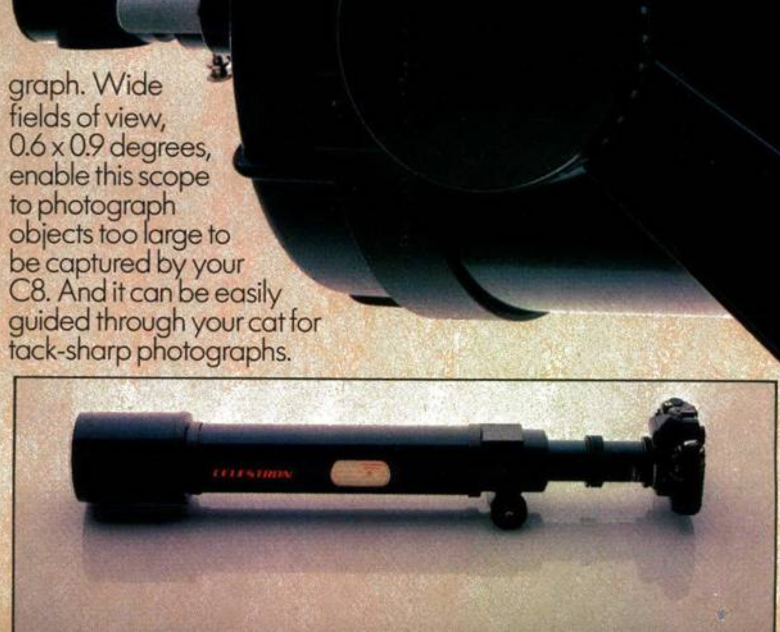
Photo Star, our 70mm fluorite astrograph, is a visual/photographic system that performs amazingly in less than optimal conditions.

Photo Star is the ideal companion scope for any C8, excellent for planetary and double-star viewing. Visually, the scope's 560mm focal length makes it perfect for Halley's Comet and large Messier objects.

The image contrast is truly amazing. And because its fluorite lens quality is so high, magnification can be increased dramatically, making *Photo Star* a superb guidescope.

As an auxiliary camera system, *Photo Star* is an excellent wide-field astrograph. Wide fields of view, 0.6 x 0.9 degrees, enable this scope to photograph objects too large to be captured by your C8. And it can be easily guided through your cat for tack-sharp photographs.





Standard equipment includes dew shield and C8 mounting brackets, rack and pinion focusing, focus lock, a camera adapter and a star diagonal. An optional multicoated tele-compressor, optically matched to the 70mm, can increase the scope's speed from f/8 to f/5.6.

YOU KNOW HOW CATS HATE WATER.

Dew Star helps increase contrast for photography and is very effective during the day.

More importantly, it prevents

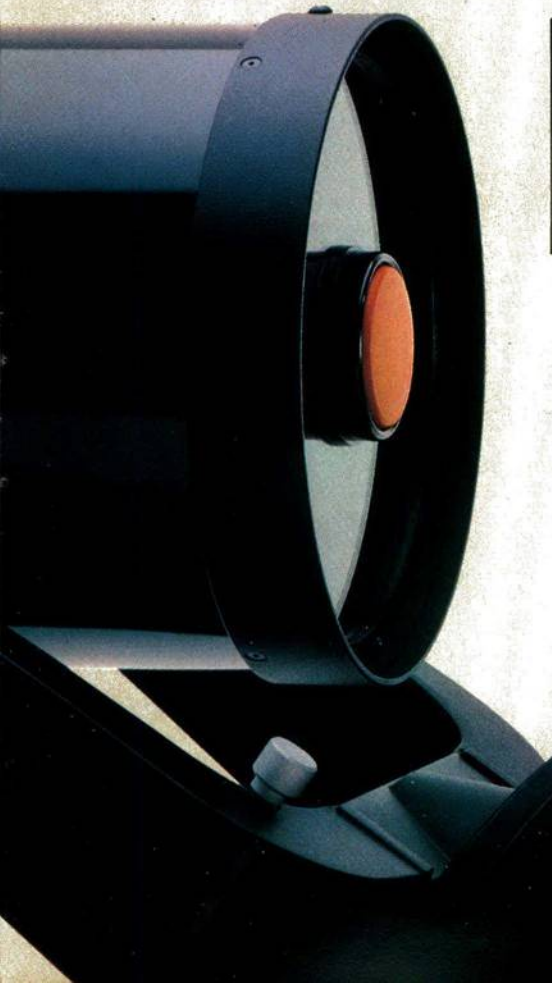
cat new tricks.

dew from forming on your cat's corrector plate, providing the maximum beneficial effect short of actually heating the plate.

Dew Star is 10 inches long and tapers at one end. The wider opening's dimensions let you snap it onto the front of your scope. And *Dew Star* is light enough that it won't upset your cat's delicate balance.

MAKE YOUR CAT MORE SOCIABLE.

Twin Star lets two people, using identical eyepieces, view at the same time. It's a great way to educate somebody new to the wonders of astronomy.



An illuminated recticle comes standard and is indispensable for pointing out specific features on the moon and planets. A star diagonal that rotates to give the viewer many viewing positions is also standard.

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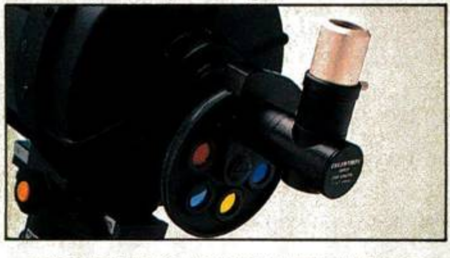
The bigger your finderscope, the easier it is to find what you're looking for. That's why we've created the 10x70 *Grab Star* finder (and a 16x70 version). These are dedicated finderscopes, to be used for distinguishing those faint deep sky objects. With either one you won't have to guess where you're pointing your cat.



LET YOUR CAT SPIN ITS WHEEL.

Our new *Chrome Star* filter wheel enhances your planetary and lunar observing at the turn of a wheel. You no longer have to remove your cat's eyepiece to change filters. Simply rotate the *Chrome Star*. It allows you to choose from up to six of your filters at one time.

SOME CATS NEED TRAINING WHEELS.

Designed for your Celestron adjustable tripod, *Trans Star* will allow you to move your cat across a carpeted room, a redwood deck or any expanse of hard ground. These solid-rubber wheels have a four-inch diameter which prevents your C8 from rolling into cracks. The wheels lock into place, giving you a solid viewing platform.

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ASTRONOMY
In Focus

Book Review Missed the Point

Sir / Dick Suiter's review of Robert T. Little's *Astrophotography — A Step-by-Step Approach* (Astronomy Reviews, July 1986) misses the point entirely. The book is, as stated in the introduction, for beginners. Mr. Little has obviously spent years fielding questions from rank beginners because he certainly answered most of mine. I don't need a detailed discussion of film hypersensitization, particularly in view of the new high speed films. But I was quite interested in knowing how to focus celestial objects on my camera's viewscreen. That alone was worth the price of the book.

Seasoned astrophotographers may have forgotten the frustrations of trying to figure out things they now take for granted. Polar alignment is second nature to them, and they no longer puzzle long and hard over questions like, "When is eyepiece projection appropriate?" Mr. Suiter probably never experienced these frustrations since he admits he could look over his shoulder and ask someone who knew.

I don't have anyone who can examine my pictures and tell me whether my problem is alignment or tracking, but I do have Mr. Little's photographs showing how certain mistakes look in the final print. (One of his pictures is captioned "Don't kick the system!")

Mr. Suiter calls the volume slim. I call it unintimidating. I've read several books and articles on astrophotography, all stuffed with more information than I needed. I'd fiddle with the complicated formulae and tables, fiddle with my telescope for a while, and then go back to worrying about the numbers again. I never took many pictures. However, after reading Mr. Little's book, I shot three rolls of film the first night.

The book does precisely what it purports to do: it gets people started taking pictures, step by step. If I'm now getting involved in such specialized areas as photo processing, it isn't because my interest was whetted by a learned tome. It's because, thanks to Mr. Little's book, I'm now taking so many pictures that my processing bill is, well, astronomical.

Mary Helm
Enid, OK

Copy Scope Refinement

Sir/ I am assembling the parts to build the "copy scope" as described in the May 1986 issue of ASTRONOMY (Equipment Atlas).

As shown in the photograph, nothing but friction between the block and the T-nut is holding the scope to the tripod. The T-nut will gradually loosen and an unexpected bump will have the scope on the ground leaving nothing but the T-nut attached to the tripod.

Mr. Bird and your readers will find that the "tripod mount" will be sturdier and last longer if it is inverted when assembled. In fact, the wooden block should be as long as the U-bolt flange so that two holes can be drilled through it.

Don Lorenzen
Saratoga, CA

The Stars at Sea

Sir / I must reply to David Epstein's letter (In Focus, May 1986) and anybody else who thinks light pollution is *not* a problem.

I have always been interested in astronomy but until recently had spent little time observing. Last year I began observing seriously and learning the constellations better. From my site, which is in a large town, I could see many stars on clear nights. I had decided that this light pollution that I'd heard so much about must be restricted to the larger cities. It wasn't until I was fortunate enough to go on a school cruise in the Mediterranean last December and January that I truly realized the beauty of the night sky.

One night the generator onboard the ship temporarily stopped due to impurities in the fuel, and only dim emergency lighting was left on. The passengers, who had previously been at the disco or watching a video, were told to go on deck for a sing-along while the crew tried to sort out the problem.

On deck, I couldn't help noticing the sky. Orion, which on earlier evenings I had found so easily, was now hardly recognizable, and the other constellations were similarly difficult to make out. Thousands of stars that I'd never seen were clearly visible. It was the most beautiful sight I've ever seen.

At last I understand just how bad the light pollution is where I live. I am sure that if it had been less, the beauty of the sky would have started me observing a lot sooner.

We should save the dark skies that we have left from the glare of artificial lighting. Nobody should mistake the few stars they see in light-polluted environs for the true splendor of the sky.

Jo Parke
Surres, England

Spangled Skyline or Starry Sky

Sir/ As an astronomy major at the University of North Carolina and an avid amateur astronomer, I would like to respond to David Epstein's letter that appeared in the May issue.

To say the least, Epstein's attitudes enraged me! I do not know of any astronomer, professional or amateur, who would rather look at the glaring night skyline of Los Angeles than a beautifully dark, starry sky. Let me also remind Mr. Epstein that although a 10-inch Dobsonian *reflector* is a wonderful instrument, the light pollution problems affecting such an instrument are nothing compared to the situation professional astronomers face where more than just visual observing and astrophotography is at stake.

Finally, how dare he call light pollution crusaders narrow-minded and selfish! I should think that after almost losing Palomar Mountain to light pollution, more people would want to do something to save our endangered night skies.

Paul J. Heafner
Albemarle, NC

Insulting Measurements

Sir / Won't you please direct your contributors to adhere to the scientific measuring system in their articles!

ASTRONOMY has been quite good in keeping astronomy on the international scientific measuring system in the past, but lately some of your articles have been insulting us with miles, feet, and the like. In fact, we all burst out laughing at the apparently new archaic unit, the "micro-inch."

The English system of measurement has no place in the sciences today. Non-scientific people need not be shielded from metrics, since it has been taught in our schools for quite some time now. Besides, metrics are appearing everywhere anyway.

John Allen
Santa Cruz, CA

— ASTRONOMY uses the units normally employed in a given field. We use both the metric system and customary United States units (inches, pounds) as appropriate. In optical fabrication, micro-inches are often, if not universally, used.

Sharp Eyes, But No Cigar

Sir/ I wish to draw your attention to two objects on the series of photos on page 108 of your February 1986 issue. The photos are of the appulse of asteroid Eunomia with M-33 in Triangulum.

While comparing the photos, I noticed two bright objects in the first (top) photo that are not in the following three photos. One is located in the upper right hand corner, the other in the upper left hand corner.

Could these be variable stars, flare stars, or novae?

Glenn K. Roberts
Halifax, Nova Scotia

— We received similar letters from a number of readers who had spotted these and other mysterious stars in the first photo that weren't in the other three. After studying the original prints in a blink comparator at our office (in which we found still more of these "stars!"), we concluded that we were looking at the consequences of a dirty negative — grit that had reversed out to star-like white dots on a positive print.

To be on the safe side, though, we contacted Janet Mattei, director of the American Association of Variable Star Observers. After graciously checking her maps and data tables, she reported that there are no known short-period variables in the immediate vicinity of M-33.

Yes, we were disappointed too.

Barlows For Observing Mars

Sir / As a Mars observer since 1956, I found the article on the present apparition of the planet fairly good for the new observer (Gazer's Gazette, June 1986). However, the author failed to mention one accessory no observer of the Moon or planets should be without: a Barlow lens.

Barlow lenses provide additional magnifications without having to purchase more eyepieces. Depending on the selection of focal lengths, an observer with three eyepieces and a Barlow has the equivalent of six eyepieces. More importantly, the observer can use longer focal-length eyepieces with their larger fields of view and greater eye relief to get the high power necessary to do worthwhile work.

Finally, a high quality Barlow can function similarly to a field-corrector lens by correcting many of the abberations inherent in low focal-ratio reflectors. Thus, a short-focus reflector can perform closer to its long-focus cousin.

For these reasons, a high-quality Barlow lens is almost universally advised for planetary observers.

Stephen W. Bieda, Jr.

Oops

The photo of M-65, M-66, and NGC-3628 on page 79 of our July 1986 issue ("Astrophotography with Tech Pan 2415 Film") was taken using a 17-inch f/4.5 Newtonian reflector and a 30-minute exposure.

Behind the Scenes

The Challenger Report

If you have any interest at all in space, I recommend that you read the "Report of the Presidential Commission on the Space Shuttle Challenger Accident," if you have not already read it. The 256-page report costs $18 and is available at any branch of the United States Government Printing Office, or from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

This document is both fascinating and frightening. According to the report, "the failure was due to a faulty design unacceptably sensitive to a number of factors. These factors were the effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing, and the reaction of the joint to dynamic loading."

It goes on. This problem wasn't something new. NASA and Morton-Thiokol had been documenting the problem since 1977, and the report reproduces some of those documents. The O-ring seal design had been rejected and then accepted, it had been tested and failed the tests, and it had failed in flight and been flown again. In short, the organization didn't work. Somehow the problem never got fixed.

NASA's engineers and bureaucrats work with the hard realities of metal, moving mass, and flame. When a decision-making process is faulty, the consequences are obvious and spectacular. If the Department of Commerce issues a faulty economic forecast, we don't see seven dead economists. When Congress passes faulty legislation, we don't see seven Senators die in a fireball in the blue Florida sky.

Beyond the "flawed decision" to launch Challenger lies the equally flawed decision to trust the future of the American space program to the Shuttle. If one expendable launcher blows up, you send another. With the Shuttle, though, we've become paralyzed, afraid to launch. That fear, which drove the decision to cancel the Centaur program, may delay the Galileo and Ulysses missions until 1990 or later, when alternative vehicles become available.

The Shuttle has a place in the space program. But it shouldn't have been — and should not be — our *whole* space program.

Sincerely,

Richard Berry
Editor-in-Chief

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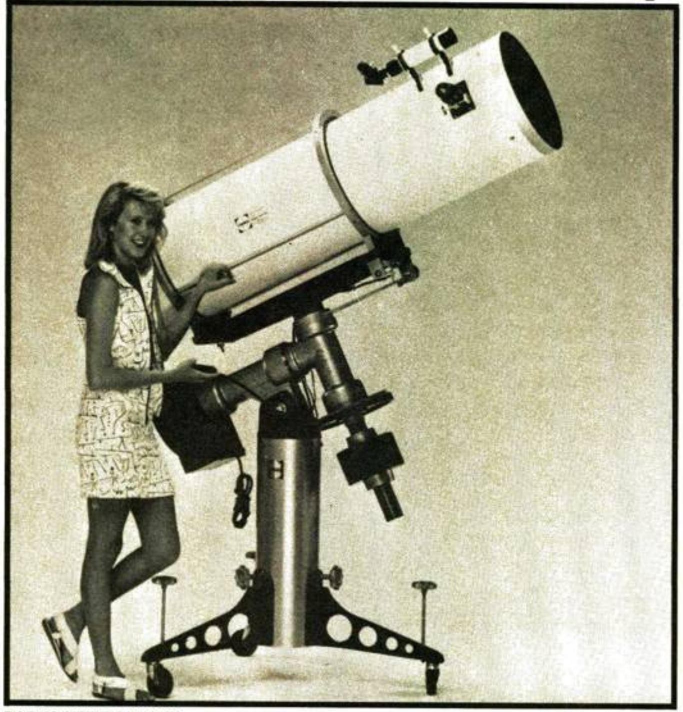

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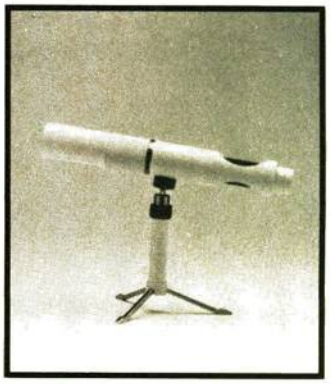

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Gazer's Gazette

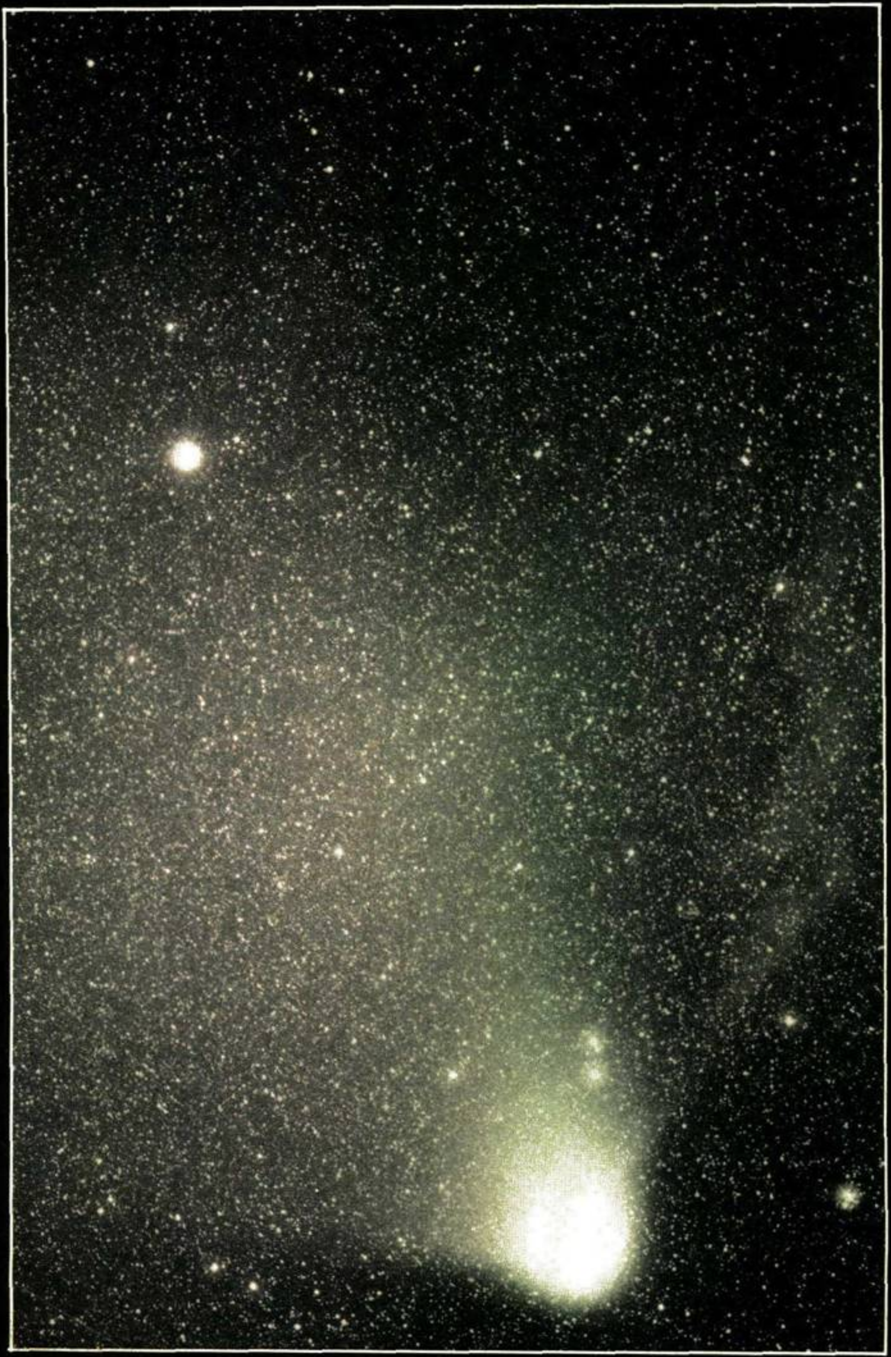
Last Look at Halley

During mid-June 1986, the excitement abruptly died. Suddenly Halley's Comet became a has-been.

In May the comet had been bright — glimmering at 4th magnitude and sporting a thin, 7°-long tail — but by early June its light faded just as the Halley-hype did. By the end of June Halley's Comet was a round, featureless glow shining at 8th magnitude.

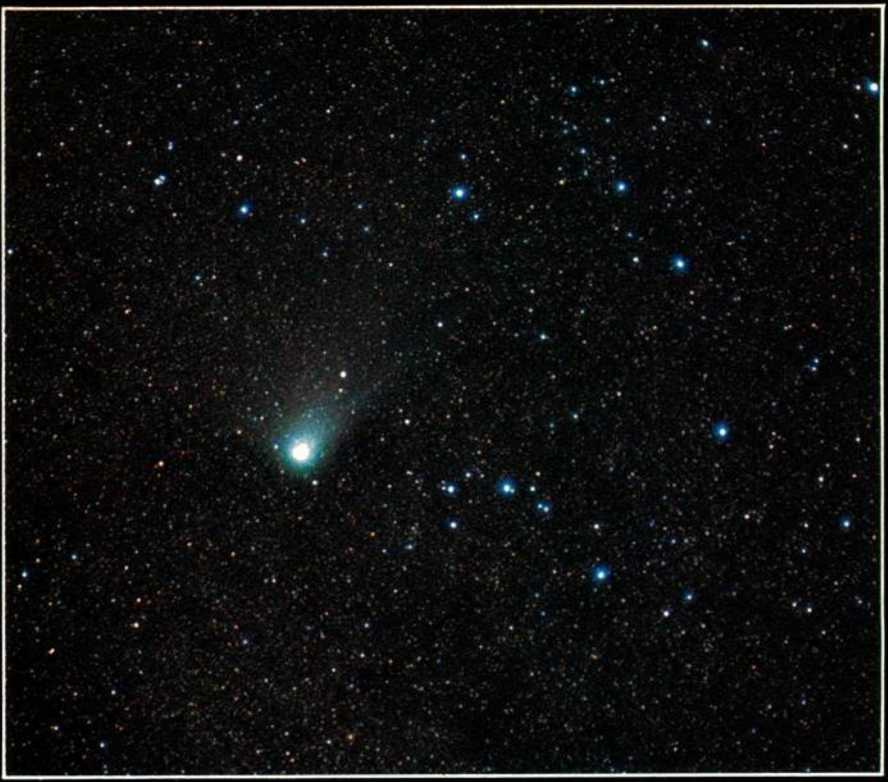
Some amateur astronomers continued to follow the famed celestial visitor with large binoculars and telescopes. For many others, however, the thrill was gone. They preferred to think back to the views they'd had in January, March, and April, when the comet was a faint naked-eye object showing detail in telescopes. During this period, whether they realized it or not, thousands of backyard observers got their last look at Halley.

Although Halley wasn't as spectacular as several others in recent memory — Ikeya-Seki in 1965, Bennett in 1970, or West in 1976 — at the height of its performance it did brighten enough and



Right: At closest approach on April 10/11, Halley's Comet appeared as a bright coma 1° across leading a broad fan or "delta" of dust. The 8°-long, sharply defined gas tail it displayed two weeks before — and would generate again two weeks later — didn't exist. Photo by Timothy Rickey, using a 5.5-inch f/1.65 Schmidt camera, hypersensitized Tech Pan film, and a 15-minute exposure.

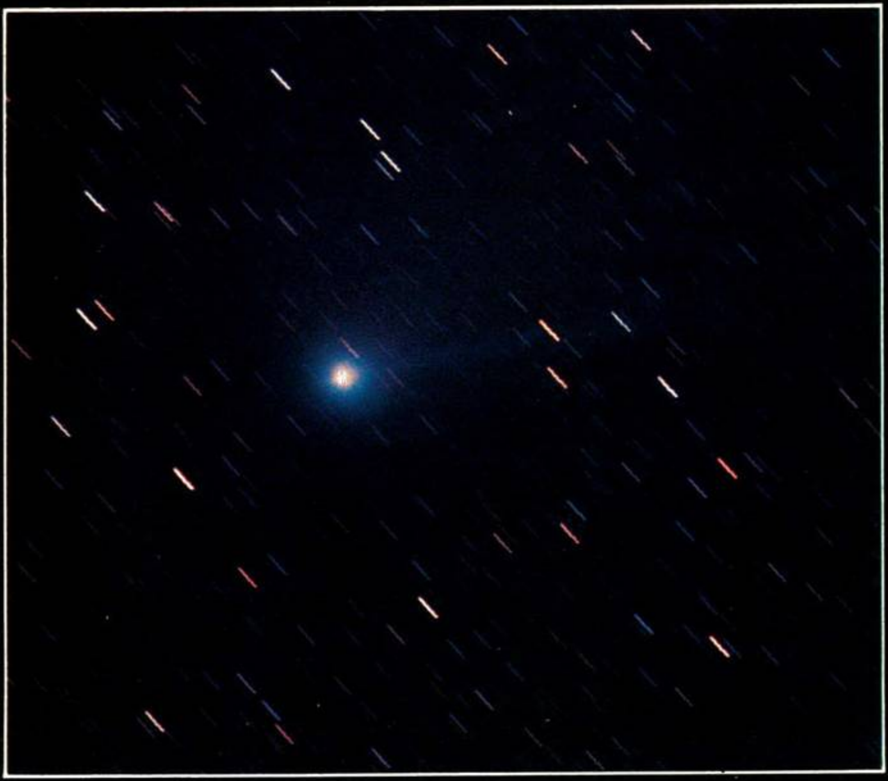
Opposite page: Despite being set against a rich Milky Way background, Halley showed a short bluish gas tail in addition to the broad dust fan on April 7. The bright, ruddy emission nebula to the left of Halley is NGC-6188; the nebula at top left is IC 4628. This photo was made at Perth Observatory by Erik Berg, Rebecca Feldstein, and Sam Jansen, students sent "down under" to observe Halley for Lowell Observatory. It is a 30-minute exposure on Ektachrome 800 pushed to ISO 3200 and made with a 50mm f/2.8 lens. Photo courtesy Brian Skiff, Lowell Observatory.

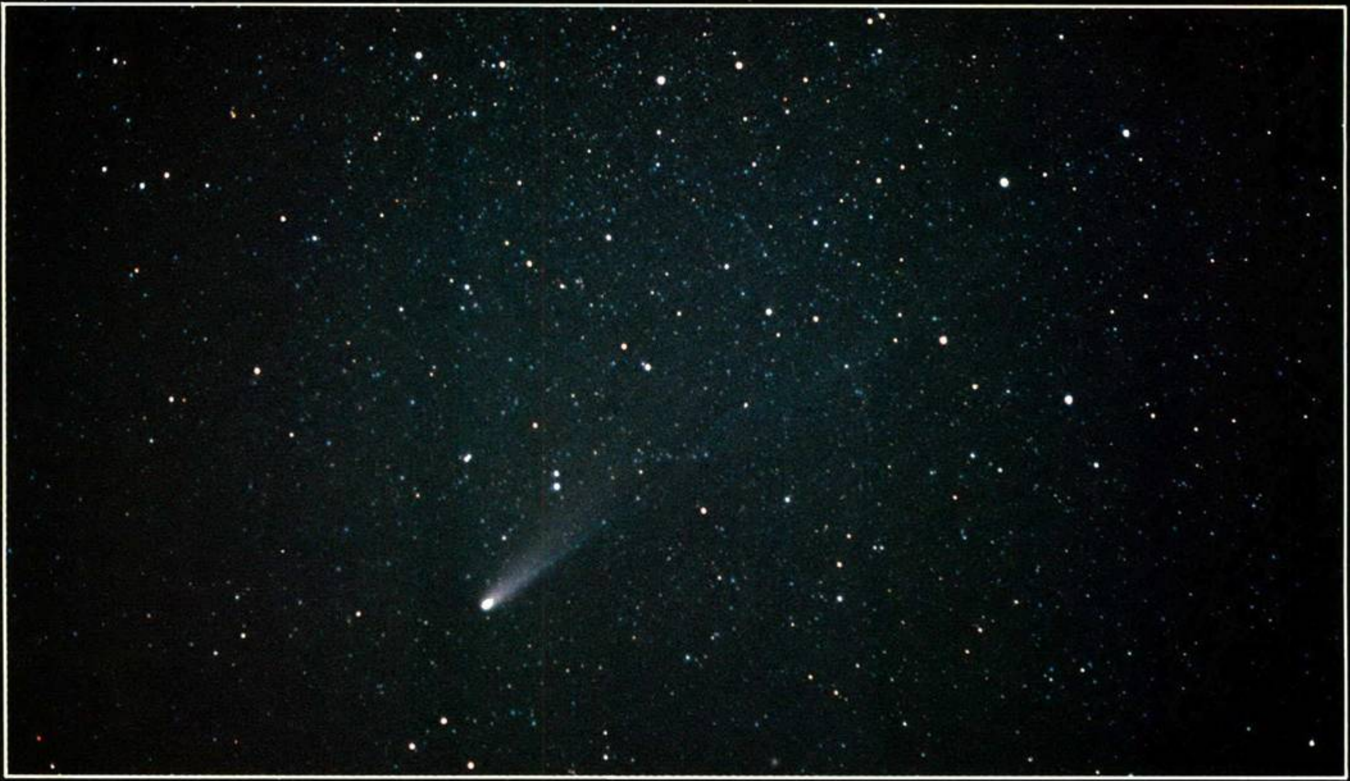


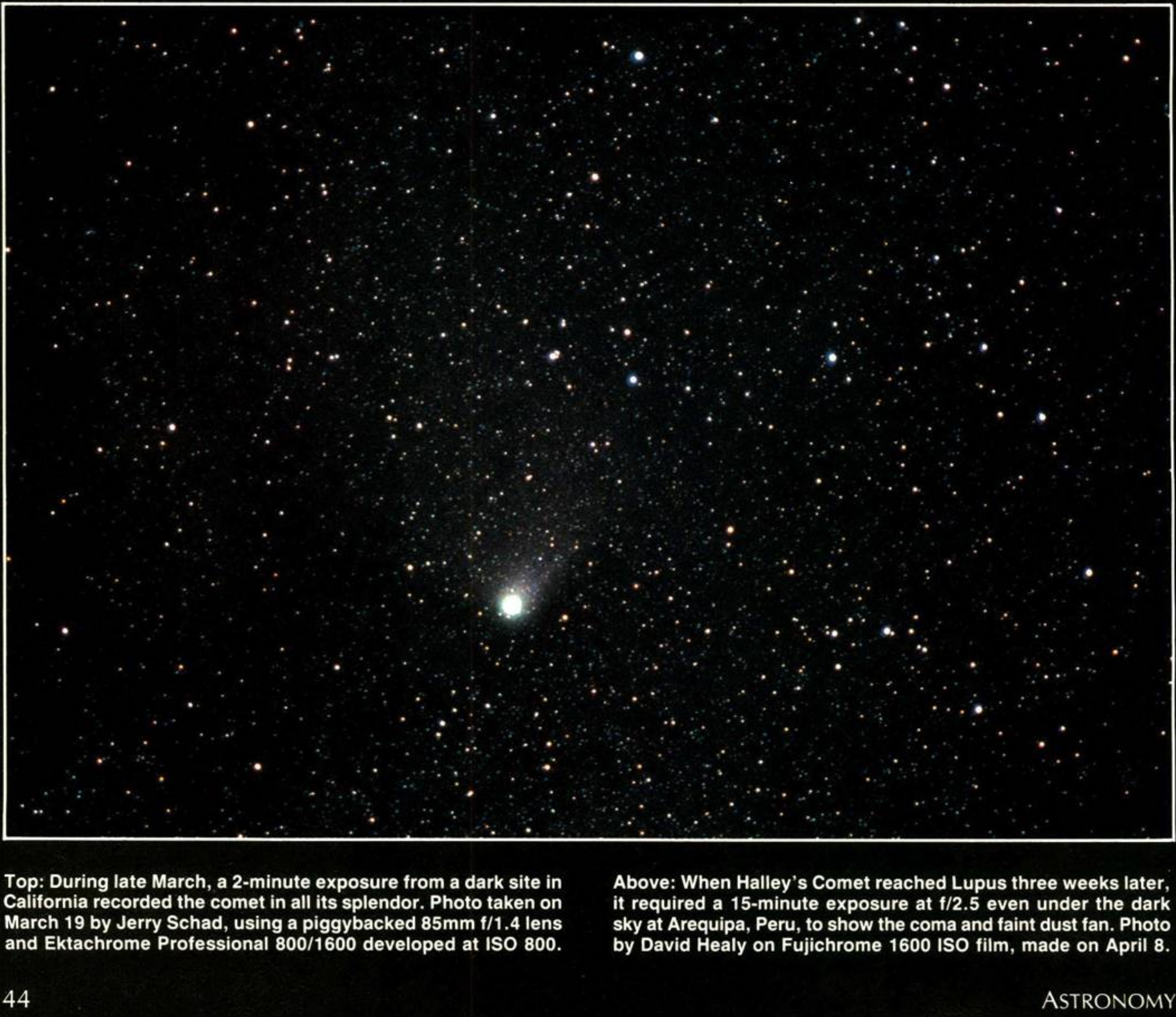
Left: During the third week of March Halley displayed a magnificent 10°-long gas tail as it moved toward Sagittarius' Teapot asterism. This photo of Halley was taken on March 20 by Eron Lee using a piggybacked 110mm f/2.8 lens, Fujichrome 400D pushed to ISO 800, and an 8-minute exposure.

Above: As seen from Yulara, Australia, on the night of closest approach, Halley showed a bluish green coma and short dust and gas tails amidst the bright blue stars of the Centaurus O-B association. Photo by Ralph Heideal using a piggybacked 135mm f/2.8 lens and a 12-minute exposure.

Below: On April 14 the comet clearly displayed signs of regaining its bright gas tail, as shown in this photo tracked on the comet's nucleus. Photo by Eric Dreher, using a 400mm f/5.6 lens, Konica 1600 ISO film, and a 30-minute exposure.

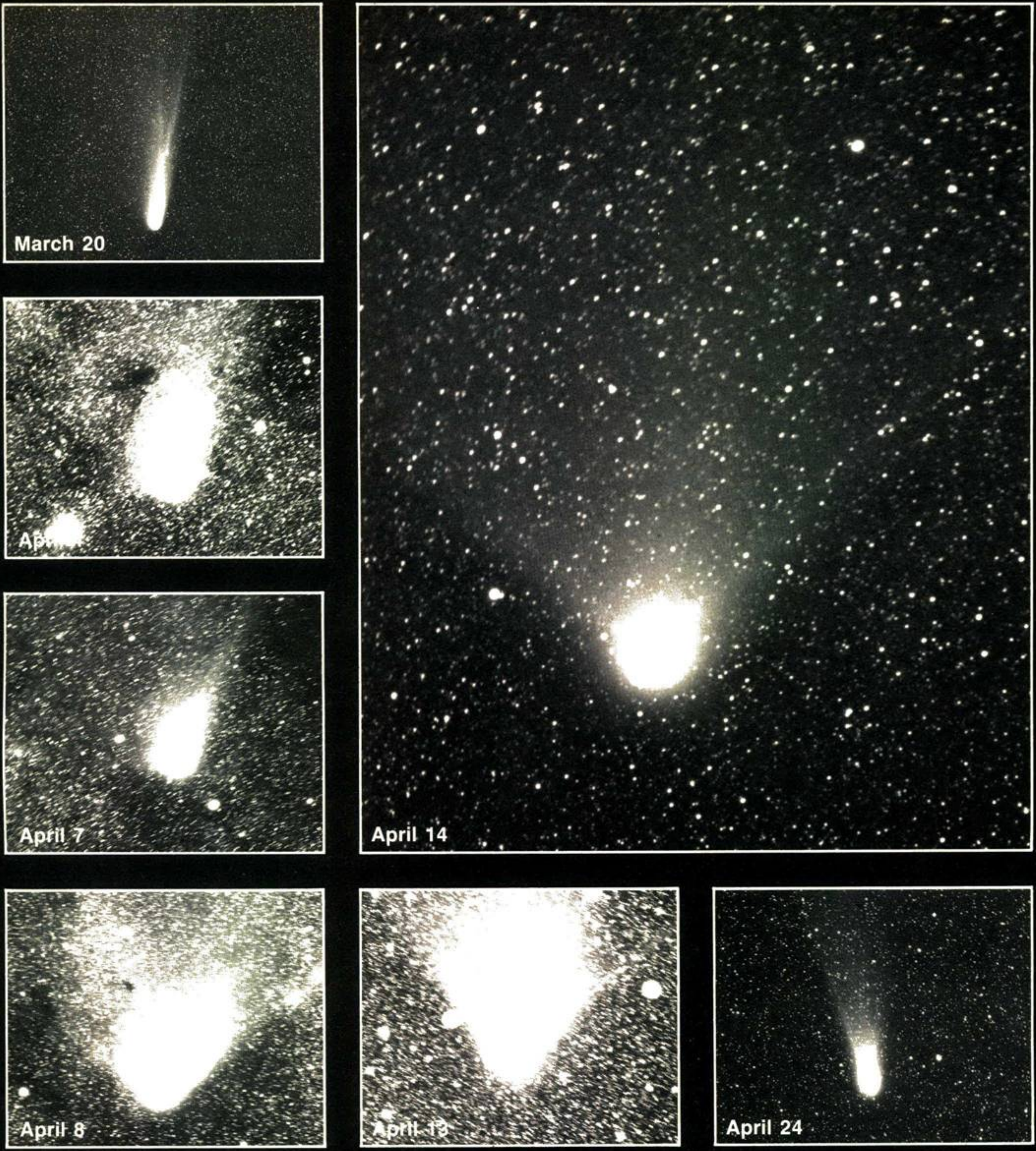






Top: During late March, a 2-minute exposure from a dark site in California recorded the comet in all its splendor. Photo taken on March 19 by Jerry Schad, using a piggybacked 85mm f/1.4 lens and Ektachrome Professional 800/1600 developed at ISO 800.

Above: When Halley's Comet reached Lupus three weeks later, it required a 15-minute exposure at f/2.5 even under the dark sky at Arequipa, Peru, to show the coma and faint dust fan. Photo by David Healy on Fujichrome 1600 ISO film, made on April 8.



This sequence of seven images shows the comet's dimming and subsequent recovery during April as it moved from Sagittarius through Scorpius, Norma, Lupus, Centaurus, and Hydra.

On March 20 Halley lay near the globular cluster M-55 and displayed an 8°-long, two-part gas tail superimposed on a fainter, wider dust tail. This 15-minute exposure on a IIaD plate was made from Joshua Tree, California. (All photos, except for April 14, by Ronald E. Royer using a 4-inch f/5 lens.)

By April 4 Halley's gas tail had virtually disappeared, leaving the comet with no more than a short dusty extension to its coma in this 15-minute exposure on a 098 plate from Hazelbrook, Australia.

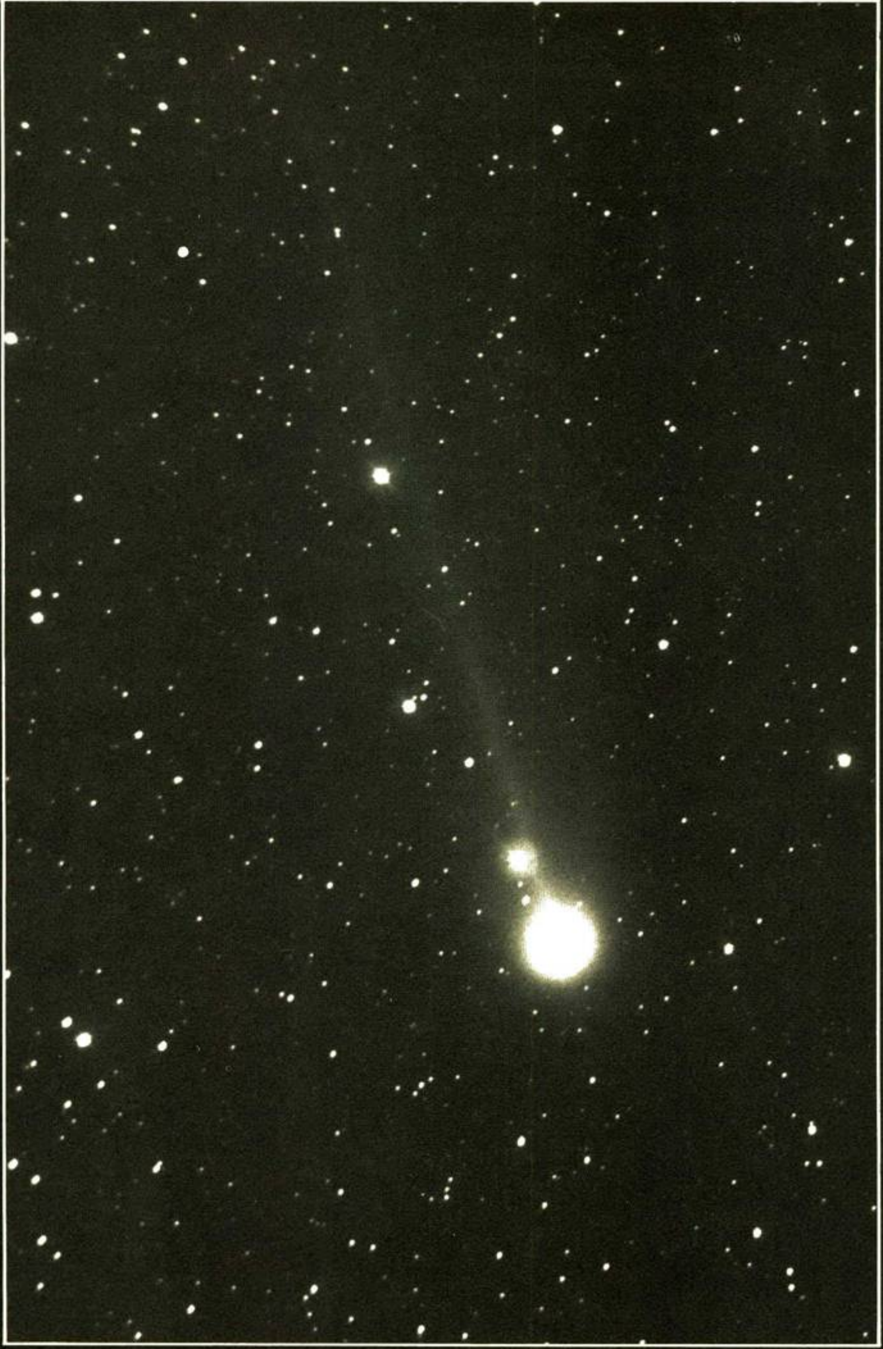
Aside from its inherent dimness, Halley lay in the rich Milky Way on April 7, making its short tail very difficult to spot in this 16-minute exposure on 098 film from Coonabarabran, Australia.

On April 8 Halley showed a wide, nearly 90° dust fan spanning 2° with a short gas tail, giving it a similar appearance to nearby globular cluster Omega Centauri. This is a 15-minute exposure on 098 from Coonabarabran.

April 12 saw Halley further develop its box-shaped dust fan but it gave little sign of any ion activity. According to Royer, the comet was "twice as bright as Omega but the same size." This is a 20-minute exposure on 098 taken from Alice Springs, Australia.

On April 14 large telescopes showed the comet as an intense, bright coma with a symmetrical envelope of dust on one side. Photo by Kent Kirkley using a piggybacked 300mm f/2.8 lens and a 30-minute exposure from Turangi, New Zealand.

After its poor showing in early April, by April 24 Halley had redeveloped a long gas tail and brightened considerably, indicating increased outgassing from the nucleus. This is a 15-minute exposure on 098 from Cairns, Australia.



By early May Halley's Comet had once again become a real comet — it shone at 4th magnitude and redeveloped a thin 8°-long gas tail. This resurgence from the comet's disappointing April performance redeemed it in the eyes of most amateur astronomers. Halley continued to be bright throughout most of May and then faded to 7th magnitude by early June. Photo of Halley on May 11 by Geoff Chester.

developed a sufficiently long tail to be an impressive sight. Even though this was probably the worst apparition in 2,000 years, when it was over most observers seemed to appreciate Halley for the show it did put on.

Amateur astronomers with moderate-to-large telescopes first saw Halley in August 1985 as it emerged from solar conjunction, moved into the pre-dawn sky, and brightened to about 15th magnitude — a tiny, fuzzy speck of light. This unspectacular beginning gave way to rapid brightening in October when Halley's coma grew to 30′ in diameter and its brightness leaped from 11th to 8th magnitude. At this point Halley lay in the constellation Taurus and was visible as a bright, circular inner coma surrounded by a large, fuzzy halo. During this period many backyard astronomers had their first view of the comet.

At the end of October Halley passed between the bright star Zeta (ζ) Tauri and the Crab Nebula, and the event was widely recorded on film by astrophotographers. But Halley really became interesting to follow early in November when it brightened to naked-eye visibility. Some 4° away from the Pleiades cluster, Halley was visible as a 6th-magnitude spot of light by mid-November. By then most skywatchers had seen it either with or without binoculars. During December Halley continued to brighten and formed a gas tail that was 2° long early in the month, which grew to 4° by month's end. As Halley moved into January's early evening sky, the first of three prime observing periods began.

During January 1986, as Halley gradually moved toward perihelion, the comet became markedly brighter — reaching 4th magnitude — and its tail grew to some 7°. Since the comet was bright, relatively large, and conveniently placed for evening observing, millions of people worldwide saw Halley in January. By the last week of the month, however, the comet had moved close to the Sun and was lost in the evening twilight. A "blackout period" ensued until Halley's re-emergence, in mid-February, in the morning sky.

Early risers saw Halley low in the pre-dawn sky during the last days of February. The comet was a 3rd-magnitude object with a coma some 2° across. The tail, which appeared wider and less detailed than in January, extended over 10°

The best Halley viewing came in March when the comet traversed the sky from Capricornus through Sagittarius, lying against rich Milky Way fields. This bright background reduced the tail's contrast against the sky. Halley was there at its height. Although the coma would be brighter in April when the comet passed close to Earth, the gas and dust tails were at their best during late March. On the evening of March 20/21 Halley underwent a spectacular disconnection event and much of its gas tail drifted away. Halley never fully recovered.

April saw Halley's Comet move through Scorpius, Ara, Norma, and Centaurus, passing near Omega Centauri and within a degree of the lenticular galaxy NGC-5128 on April 15. For Northern Hemisphere viewers Halley lay low on the horizon. Halley's coma shone brighter than 3rd magnitude, but it had only a faint, 2°-long dust tail. It was not an impressive sight.

In May Halley moved northward through Crater and Hydra, dimming to 4th magnitude but re-forming a faint 7° ion tail. Curiously, the view early in May was much better than that early in April, despite the fact that Halley was actually brighter and closer in April. This simply confirms the notion that comets are unpredictable creatures.

Halley is in conjunction with the Sun on September 17, but will reappear in October's morning sky and remain visible as a faint patch of light for several months.

Some of us will still be out under the stars to follow Halley out, even though others will remember Halley at its best and let it go at that. Whatever you do, be sure to remember that special view of a comet — your last look at Halley. *David J. Eicher.*

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#105 2" Altazimuth	28X, 78X	7°12'	50 mm, f/14	4X—19 mm, 7°12' field	26 in	54 in.	9 lb.
#114 2.4" Altazimuth	35X, 50X, 72X, 100X	7°12'	60 mm, f/15	6X—24 mm, 6°22' field	34½ in.	58 in.	16 lb.
#128 2.4" Equatorial	35X, 50X, 72X, 100X, 129X	7°12'	60 mm, f/15	6X—2 mm, 6°22' field	34½ in.	60 in.	24 lb.
#140 3" Altazimuth	48X, 67X, 96X, 131X, 171X	4°20'	75 mm, f/16	8X—30 mm, 4°22' field	47 in.	59 in.	23 lb.
#142 3" Equatorial	48X, 67X, 96X, 131X, 200X	4°20'	75 mm, f/16	8X—30 mm, 4°22' field	47 in.	59 in.	46 lb.
#131-C 3" Compact Equatorial	48X, 67X, 96X, 131X, 171X, 200X	4°20'	75 mm, f/16	8X—30 mm, 4°22' field	19 in.	60 in.	32 lb.
#150 4" Altazimuth	60X, 83X, 120X, 167X, 214X, 250X	3°22'	100 mm, f/15	10X—40 mm, 2°54' field	63 in.	64 in.	50 lb.
#152 4" Equatorial	38X, 60X, 83X, 120X, 167X, 214X, 250X	3°2'	100 mm, f/15	10X—40 mm, 2°54' field	63 in.	66 in.	100 lb.

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Equipment Atlas

Astrophotography With Image Intensifiers

by
Scott McGurk

The age of electronic astronomy has arrived. Nowadays amateur astronomers talk about photomultipliers, photodiodes, CCD sensors, and image intensifiers. Because all of these devices detect low-intensity light more efficiently than photographic film does, they would appear to have great potential for helping us take better pictures.

But photomultipliers and photodiodes only measure the brightness of a single image point, and they require interfacing with an electronic recorder. CCD image sensors have low to medium resolution and they require computer-image processing. Only image intensifiers have medium to high resolution and can produce an image that can be viewed or photographed directly.

How Image Intensifier Tubes Operate

Several different types of image intensifier tubes are available for amateur astronomy. Some of these tubes are incorporated in ready-to-use commercial products (somewhat confusingly called "image intensifiers") designed to fit your telescope. They typically cost between $2,000 and $4,000. Although some astronomy enthusiasts can afford such expensive accessories, many others cannot. However, it is possible to design and construct your own image intensifier system for just a few hundred dollars. But before you rush out and try to build such a unit, it is important to determine your imaging requirements. Understanding something about how image intensifier tubes work and what their limitations are is the first step.

The two most common tubes available are the "diode" and "micro-channel plate" types, shown in schematic form on the next page. The image formed by the telescope is focused onto a fiber-optic window consisting of millions of microscopic optical fibers aligned parallel to each other. The light is carried by these fibers, which are typically 0.0005 inches (12 micrometers) in diameter, from the front of the window to a thin coating on the other side.

Known as the photocathode, this light-sensitive coating is a vacuum-deposited layer of alkali metals. When a photon of light strikes the atoms in the coating, electrons are ejected. The wavelength of the incoming photon of light and the composition of the photocathode determine how many electrons are released.

The most common type of photocathode is called an S-20 photocathode. It is sensitive to the light of the entire visible spectrum, with a peak sensitivity to yellow-green light with a wavelength of about 550 nanometers. The "extended S-20" photocathode, which is also fairly common, extends the sensitivity out past 800 nanometers into the near-infrared.

The electrons emitted from the photocathode represent the input image in that they have a position and flux proportional to the number of original photons. Inside the tube, these electrons are accelerated away from the photocathode and focused to the output side of the tube. The acceleration is achieved by applying a very high positive voltage relative to the photocathode (cathodes are always negative). The electrons are focused by a cone-shaped electrode in the middle of the tube in a process called electrostatic focusing. Both the photocathode and receiving surface must be curved to achieve a sharp focus of the electrons.

At this point we have an upside-down, backward, and amplified image at the other side of the tube. Where did the amplification come from? The energy of the electrons is directly proportional to the square of the accelerating voltage, and that voltage is very high — up to 15,000 volts. The desired amplification determines what happens next.

If low gain is sufficient for your observing needs, then you want a diode inverter tube. In this intensifier design the focused electrons strike a phosphor screen. The type of phosphor used most often, a P20 phosphor, has a green-yellow peak light output. The phosphor screen produces light intensities proportional to an electron's energy and thus returns us to an image consisting of photons. But now there are 25 to 40 times more photons than originally struck the input window! This light is transferred out of the tube through a fiber-optic output window.

If you need high gain, then you want a micro-channel plate intensifier. In this tube, electrons are focused into a micro-channel plate (MCP) amplifier before they go to the output phosphor screen. The MCP is similar to a fiber-optic window but consists of millions of microscopic tunnels rather than optical fibers. A voltage applied to the MCP causes electrons to accelerate inside the tiny tunnels.

When a single electron enters one of the tunnels it soon strikes the wall and, because it has gained energy, ejects several secondary electrons. These electrons travel down the tunnel a short distance, then hit a wall and kick even more electrons off the tunnel wall. The number of electrons exiting the channel for each one entering depends very strongly on the voltage across the MCP. This means that the gain of the system can be varied over a wide range, typically from 10 to over 15,000 times. The electrons exiting the MCP are focused onto the phosphor by placing it extremely close to the MCP output. This is called "proximity" focusing. A fiber-optic output window completes the device.

Numerous variations exist. For example, some recent tubes utilize only proximity focusing, instead of electrostatic focusing. Others have special photocathodes or output phosphors. In general, these tubes are hard to find on the surplus or used market and they are very expensive brand-new. For the amateur, then, the diode inverter tube and micro-channel plate tube are the most practical and easiest to find.

Which is the best tube for you? If you want the highest possible resolution, fixed low gain, and lowest cost, then a used, surplus diode inverter would be the answer. Used diode tubes with 25-millimeter-diameter image areas, 25 to 40 visible light gain, 60 line-pairs/mm resolution, and complete power supplies have been advertised for under $200 within the last year.

On the other hand, if you're willing to sacrifice some resolution for variable high gain and greater red-light sensitivity, then an unused surplus MCP tube could be acquired for $1,500 to $2,000. It would have a 25mm-diameter image area, maximum visible light gain of 15,000 times, 30 line-pairs/mm resolution, and a built-in miniature power supply. In between these two examples are stacked tube assemblies of two or three diode tubes in series and used and/or low-quality MCP intensifier tubes.

Image Intensifier Astrophotography

Image intensifier tubes make it easy to get amazing results in astrophotography. Dramatically reduced exposure times mean fewer accumulated guiding errors, so the resulting images are sharper. If it takes 100 photons to produce a black spot on film, then an intensifier with a gain of 100 should produce a black spot on the film with only one incoming photon. (Actually, it's not quite so simple. The photocathode does not respond to every incoming photon because it is not 100 percent efficient, but when it does respond, the tube outputs 100 photons.)

Even though it is possible to have each photon register an image on film, you won't want to use exceedingly high gains and short exposures routinely. For example, let's say you decide to photograph a very dim nebula. After the image passes through your telescope system, only 1,000 photons per second are detected by the intensifier. You decide to "crank up" the gain to keep the exposure at 10 seconds. After you develop the film and get a perfectly dense negative, you notice that the image appears grainy and soft. There are two reasons why this has occurred.

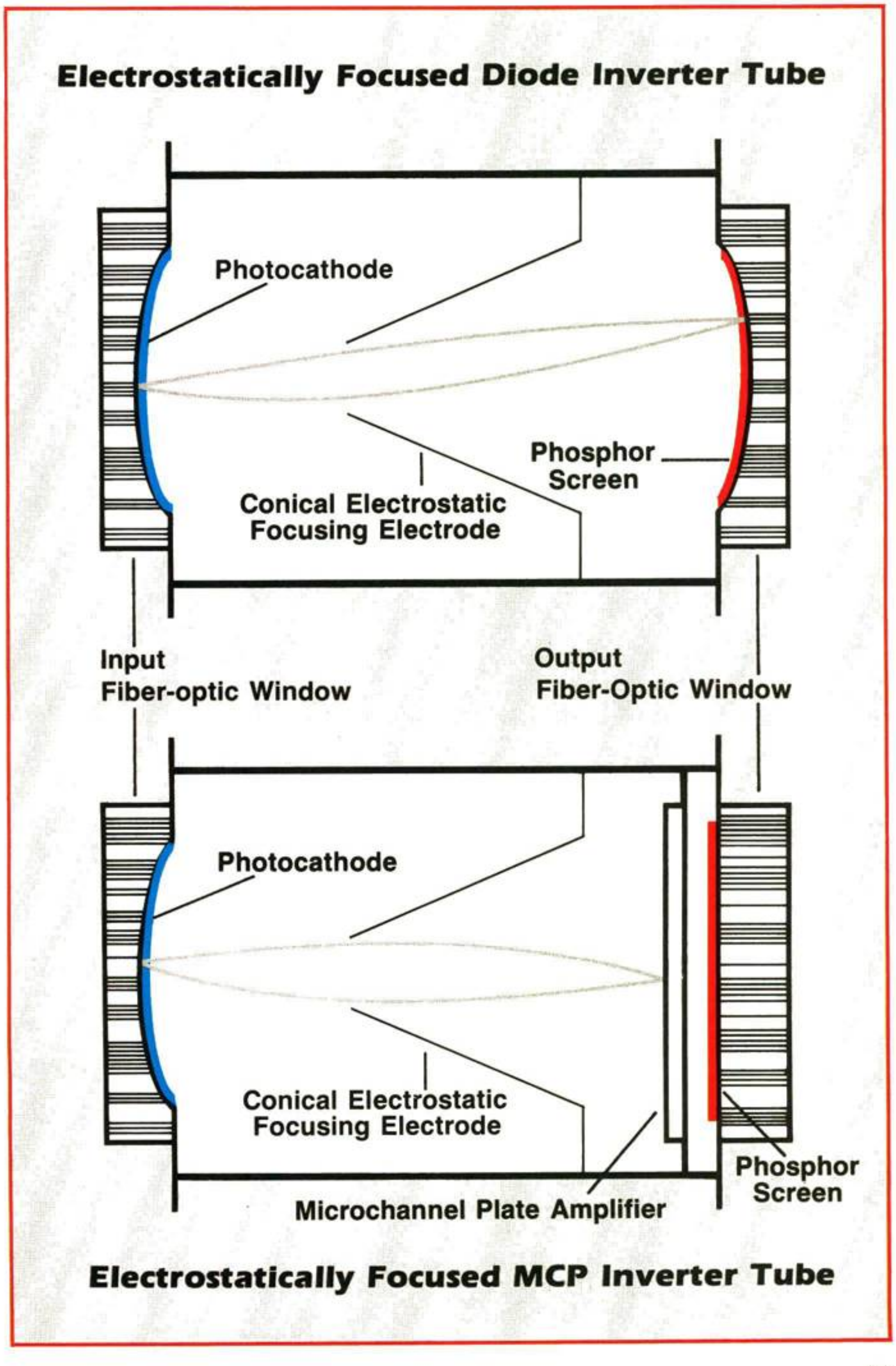
The first reason is that your 10-second exposure recorded 10,000 photons, which is statistically not enough to produce good resolution and a smooth range of tones in the image. Its quality is limited by the number of incoming photons. By using a lower gain and longer exposure time, you would have been able to capture and record more photons.

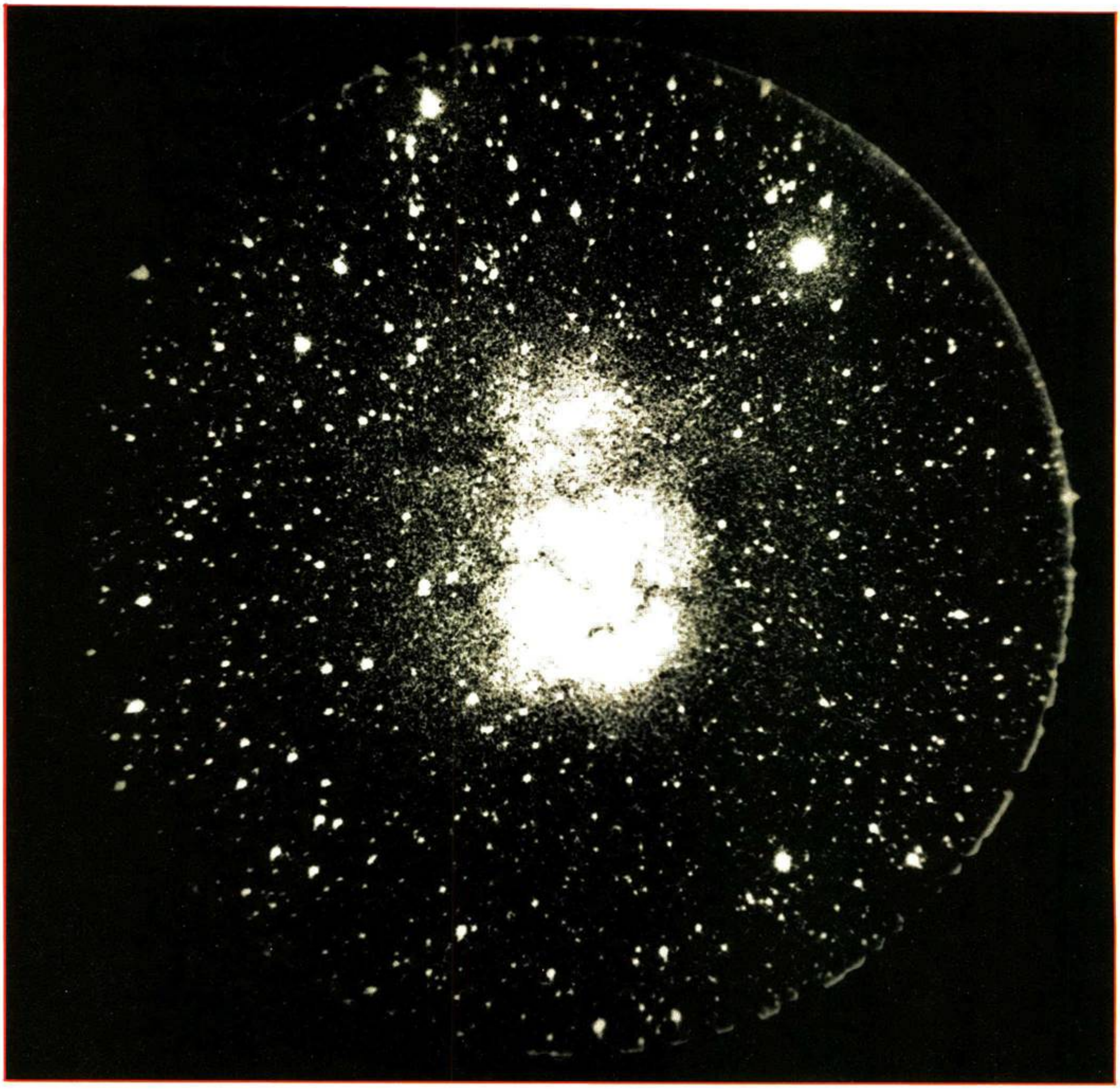
The second reason is that the intensified images are noisy. All electronic signals contain noise and when the signal is amplified, so is the noise. The electronic "signal" in intensifier tubes is the stream of electrons ejected from the photocathode. The "noise" consists of random electrons ejected from the photocathode by thermal excitation and rare interactions with ionized gas molecules. At room temperature, the noise appears as a constant, dim illumination on the output screen even when there is no light falling on the sensitive face of the tube. Long exposures with an intensifier help by taking advantage of the film's reciprocity failure. This usually undesirable feature actually helps by increasing the contrast between the image and the background noise.

Another common mistake in the use of intensifiers is the way in which the image is transferred from the output of the tube to the film. It's possible to produce acceptable images by taking a photo of the output phosphor screen, but it is terribly inefficient. With a single f/1.0 transfer lens only about 6 percent of the light from the screen is transferred to the film. Furthermore, a wide-open lens has a curved, shallow depth of field, making accurate focus difficult. If the intensifier is a high gain unit with medium resolution, then these problems can be overcome by purchasing a special relay lens designed to transfer between 12 and 24 percent of the light output, or by stopping down the lens for sharp focus across the entire output screen. The gain of the intensifier can be increased to compensate for the large loss of light.

But there's a better way. For the high-resolution, low-gain image intensifier tubes, the solution is to transfer the screen output directly to the film without a lens. By pressing the film directly against the fiber-optic output window with a bit of foam rubber, nearly all of the light from the phosphor is transferred to the film and none of the tube's resolution is lost.

One last consideration is the type of film used to record the image. In the case of a diode inverter, where the resolution is 60 to 70 line-pairs per millimeter, film with very high resolution is required. An ordinary film like Tri-X would not be


Electrostatically Focused Diode Inverter Tube
Photocathode
Phosphor Screen
Conical Electrostatic Focusing Electrode
Input Fiber-optic Window
Output Fiber-Optic Window
Photocathode
Conical Electrostatic Focusing Electrode
Microchannel Plate Amplifier
Phosphor Screen
Electrostatically Focused MCP Inverter Tube

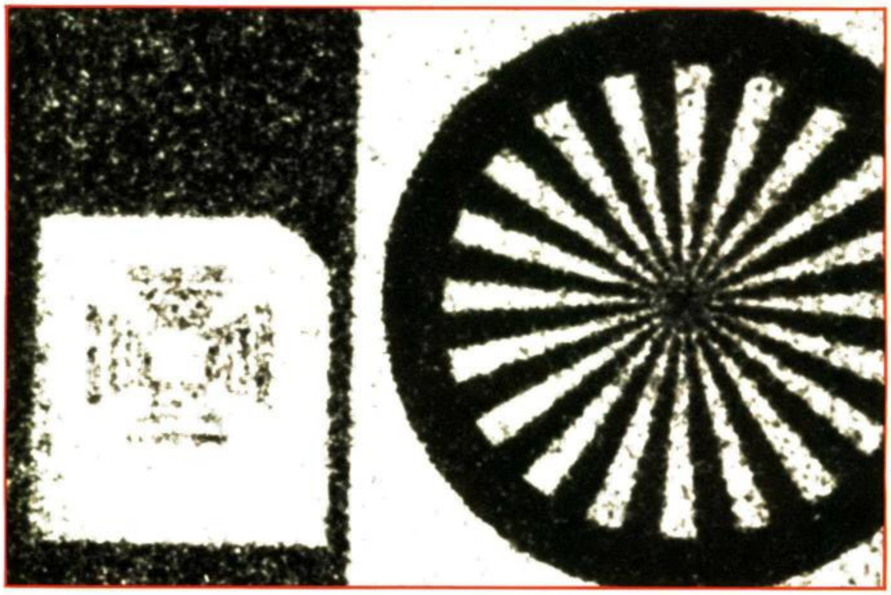


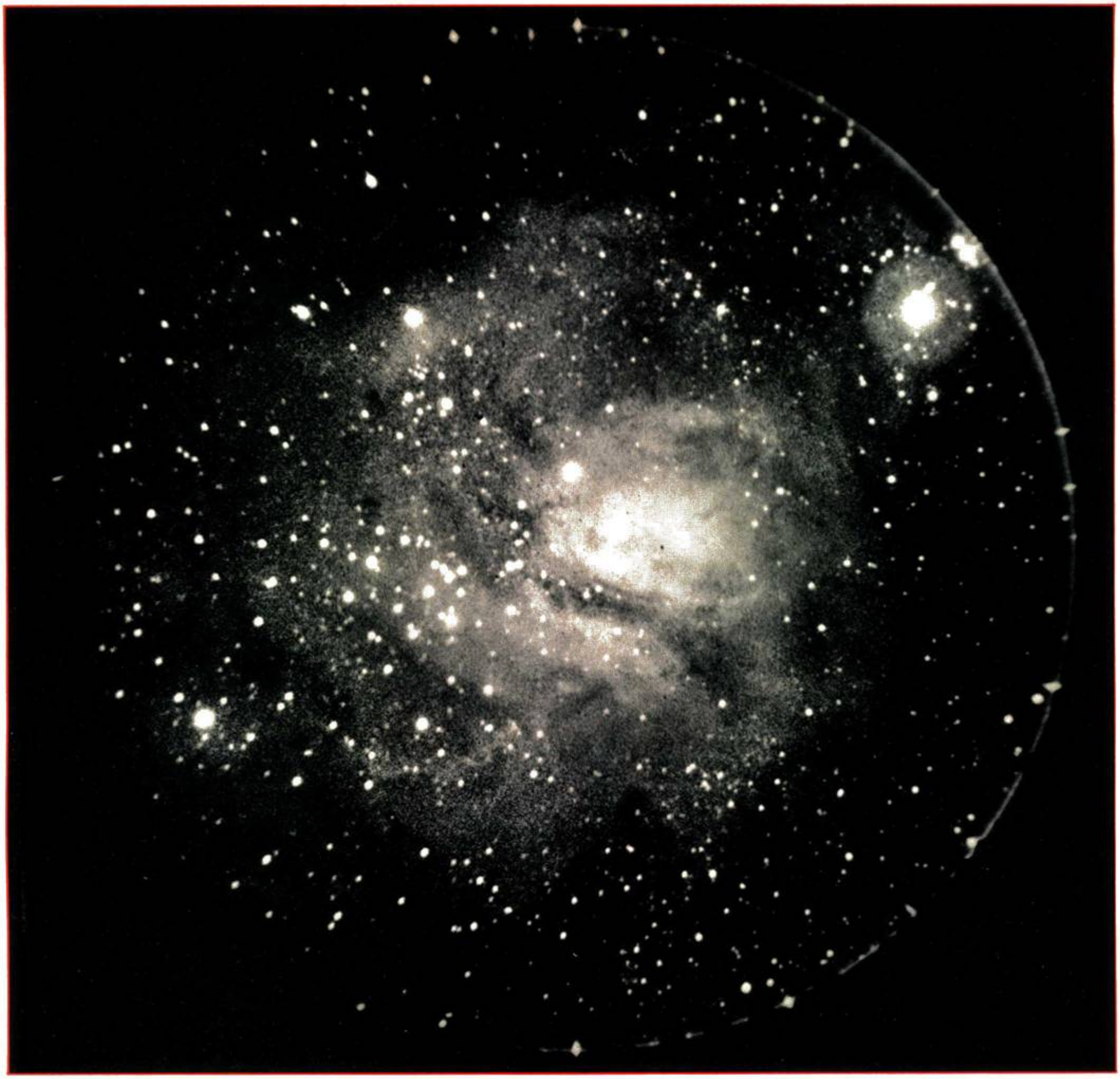
acceptable since it only has 50 line-pairs per millimeter resolution for low contrast images and little contrast control by varying its development time.

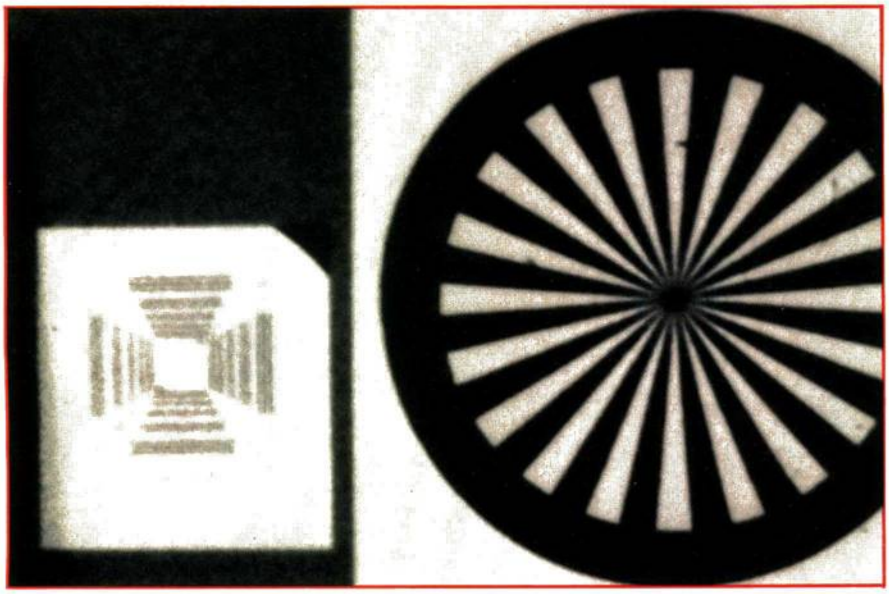
Kodak Technical Pan 2415 film is a good selection, having resolution well in excess of 100 line-pairs per millimeter and a wide contrast range. Even with MCP intensifiers, where the resolution is about 30 line-pairs per millimeter, Technical Pan is a good choice to avoid image degradation. Furthermore, Tech Pan's contrast is easily tailored to complement any image tonality.

Photographic Results

After studying specifications for a number of image intensifiers, I decided to design and build an intensifier camera-viewer combination based on a 25mm MCP inverter tube. I wanted a system I could "look" through, take photos with, and videotape with.

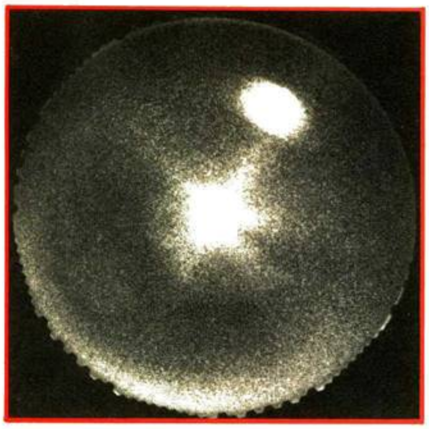


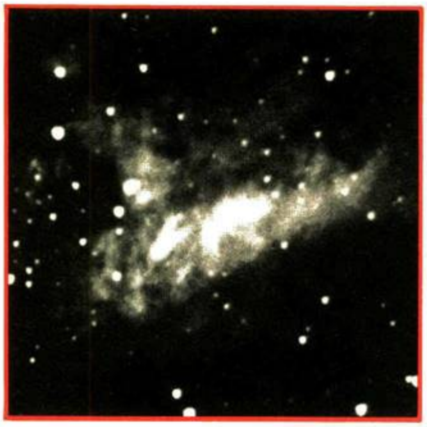




Left hand page: By using his intensifier with a gain setting of 3,000, Scott McGurk cut this exposure of the Trifid Nebula to a mere 10 seconds, but the image is unsatisfying because there were not enough photons to produce a full tonal range. The image is a 10-second exposure on Tech Pan 2415 film using an 8-inch f/10 SCT. The photon-limited image of a test chart, bottom left, is a 5-second exposure with an intensifier gain of 17,000. Note that both the resolution and image quality are poor.

Above: Setting the intensifier gain to 250 allowed a longer exposure and gave much better image quality. The Lagoon Nebula, above, required a 120-second exposure on Tech Pan 2415 film with an 8-inch f/10 SCT. Note that the faint parts of the nebula are still photon-limited even though the bright parts are not. The test chart, left, is a 720-second exposure with the intensifier gain at 150, but it is otherwise identical to the chart on the opposite page.



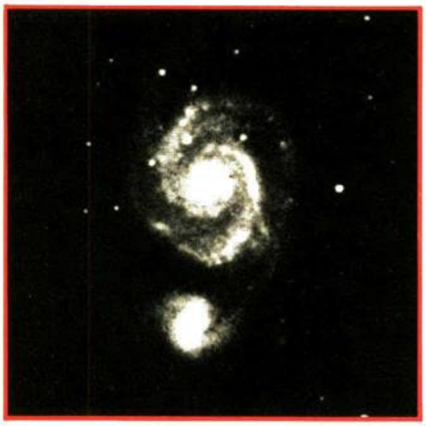


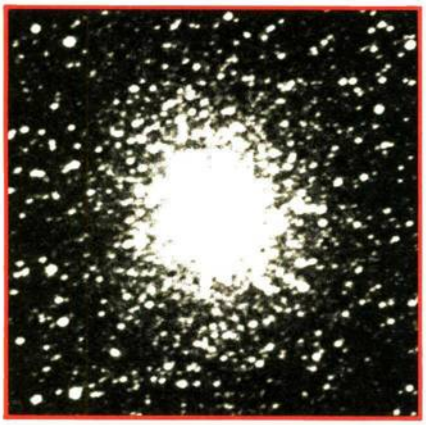
Above: This "dark noise" exposure shows the characteristic noise pattern of the tube present even when no light falls on a tube. The intensifier gain was set to 17,000 for this 300-second exposure. The noise pattern is approximately 50 times fainter than typical celestial scenes.

Top right: With an 8-inch f/10 SCT, the Omega Nebula photo required only a 2-minute exposure on Tech Pan 2415 film. For this image, the author used a relay lens and an intensifier gain of 8,000. Because relay lenses are inefficient, the effective gain of the system was very much lower.

Middle right: Spiral arms show clearly in this 2-minute exposure of M-51, the Whirlpool Galaxy, in Canes Venatici. The intensifier gain was 250. Scott McGurk used Tech Pan 2415 pressed directly against the output fiber-optic window of the image intensifier tube.

Bottom right: For objects that have no middle tones, you can turn the gain as high as you like. This image of the globular cluster M-22 was recorded in just 10 seconds on Tech Pan 2415 film using an intensifier gain of 3,000. All photographs by Scott McGurk.





I decided that lower resolution was a fair trade-off for the increased flexibility offered by a MCP tube. A problem I encountered was that the best MCP tube I could find (made by Varo) only had a gain range from 1,500 to 15,000. However, I had to be able to lower the gain so photographic exposures would not be too short and would not include enough photons to define the image. Fortunately, I was able to override the gain control in the tube's built-in power supply. The finished intensifier system has an average resolution of 34 line-pairs per millimeter, visible light gain from 15 to 15,000, extended spectral sensitivity to 900 nanometers, less than 5 percent geometric image distortion in the center, and runs for ten hours on two AA batteries!

I use this system on my 8-inch f/10 Schmidt-Cassegrain for viewing, photography, and videotaping. When I view, I use different gain settings depending on the magnitude, filters used, and dark adaptation of my eyes. However, I've found that direct viewing with the intensifier has few advantages since the eye is such a remarkably sensitive instrument.

To make astrophotos, I press strips of Technical Pan film directly against the output fiber-optic window or use my 35mm SLR camera and a special relay lens. Depending on the brightness of the subject, the filters in the optical path, and the magnification, I use gain settings between 30 and 15,000, with exposures between 10 seconds and 10 minutes.

For videotaping, I set the gain at the maximum 15,000, then focus a black-and-white television camera on the output screen. I have successfully taped the Orion Nebula, the Andromeda Galaxy, and a couple of planetaries and clusters. However, this method of transferring light to the TV camera is very inefficient.

For better results with video, I am designing a system using direct fiber-optic transfer to a vidicon television camera tube. An improved version of this system will soon be installed at the Orange County Astronomers' new observatory near Anza, California, on the club's 22-inch Cassegrain telescope. We plan to use intensified video to guide long-exposure photographs, to display on monitors for visiting groups, to broadcast to the Los Angeles area on amateur TV, and to tape astronomy programs for presentation at schools and seminars.

The age of electronic astronomy is here. I predict that within ten years, image intensifiers will become so common for black-and-white deep-space photography that telescope manufacturers will offer them as a standard accessory.

Scott McGurk is a research engineer with a B.S. in chemical engineering. For a living, he performs complex computer simulations of fluid flow. He has been interested in amateur astronomy for the past fifteen years, especially in "electronic" astronomy. Scott is a member of Orange County Astronomers and the Electronics-Oriented Astronomers.

Sources of Image Intensifiers

The supply of new and used image intensifiers varies considerably. In 1984 and 1985, all types of raw tubes and power supplies were readily available. You could even buy new tubes from major manufacturers. In late 1985, the situation changed for the worse. Large military contracts began to dry up the "new" tube market, and the "used" tube market changed direction as firms began to offer only complete units rather than parts.

"Raw" tubes and power supplies to build your own unit can still be found, however, if you're willing to look hard enough. Astronomy and aerospace swapmeets and bidding on military surplus small lots are your best bets.

When you find a tube that you want to buy, be sure to power-up the tube and check for blemishes. A new or good used tube will have just a few of these annoying light or dark spots in the output image.

New tubes are hard to buy. Many firms that manufacture image intensifiers have huge military contracts and will not deal with individuals. However, one firm that has dealt with individuals in the past is:

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Authorized Meade Dealer

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The best-selling ultra-portable telescope is the Meade 2045. It's complete with two eyepieces, high transmission coatings, finderscope, drive, tabletop tripod, slow motion controls, setting circles, photo tripod adapter, star diagonal, case, and more — making it perfect for use as a telescope, terrestrial spotting scope, or 1000mm f/10 telephoto lens. $\$1200^{00}$ list, until September 30, the 2045 is **sale-priced at only $\$595^{00}$!**

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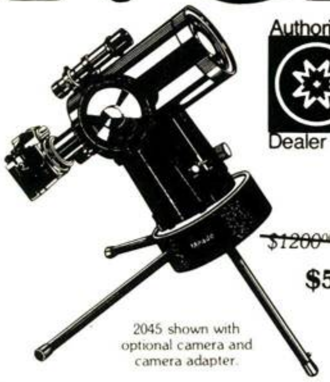

~~$\$1200^{00}$~~

$595

2045 shown with optional camera and camera adapter.

Some optional extras for the 2045 and 2045/LX3

Meade field tripod and wedge for convenient use anywhere, *$\$380^{00}$ list*	**$\$285^{00}$**
Meade #62 camera adapter, with T-ring (specify camera), *$\$64^{00}$ list*	**$\$43^{95}$**
Meade #36 hand controller for 2045/LX3, *$\$150^{00}$ list*	**$\$99^{50}$**
Meade #38A declination motor for 2045/LX3, *$\$150^{00}$ list*	**$\$99^{50}$**
Meade #43 12VDC drive corrector for 2045, *$\$120^{00}$ list*	**$\$84^{50}$**
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Meade off-axis guider system, with illuminated reticle, *$\$220^{00}$ list*	**$\$164^{00}$**

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Meade 2080/LX3, complete, with multi-coated silver optics, *$\$3220^{00}$ list*	**$\$1895^{00}$**
Meade 2120/LX3, complete, with multi-coated silver optics, *$\$5290^{00}$ list*	**$\$2899^{00}$**
Meade #36 hand controller for 2080/LX3 and 2120/LX3, *$\$150^{00}$ list*	**$\$99^{50}$**
Meade #38 declination motor for 2080/LX3 and 2120/LX3, *$\$150^{00}$ list*	**$\$99^{50}$**
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Meade 826C 8" f/6 Newtonian reflector, complete, *$\$1590^{00}$ list*	**$\$949^{00}$**
Meade #47M dual axis drive corrector for 628C, 645C, and 826C, *$\$430^{00}$ list*	**$\$299^{95}$**
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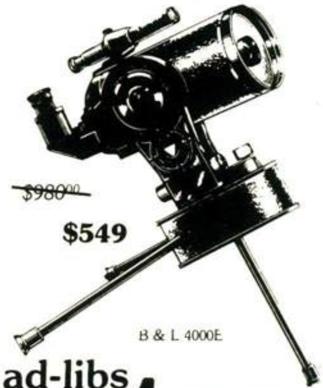
Meade camera adapter, with T-ring (specify scope and camera), *$\$64^{00}$ list*	**$\$43^{95}$**
Celestron CO-114 4.5" f/8 Newtonian reflector, complete, *$\$750^{00}$ list*	**$\$399^{00}$**
Celestron CO-60E 2.4" equatorial refractor, complete, *$\$600^{00}$ list*	**$\$379^{00}$**
Celestron Super C8 Plus, wedge, tripod, *$\$2930^{00}$ list*	**$\$1699^{00}$**
Celestron Super C8 Plus, wedge, tripod, Starbright coatings, *$\$3130^{00}$ list*	**$\$1799^{00}$**

Call for price quotes on the many other scopes and accessories available.



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$549

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B & L Criterion 4000 Enhanced

Here's a super all-purpose 1200mm f/12 astronomical telescope, spotting scope, telephoto lens — all in one! *Enhanced aluminum* mirrors, high transmission optical coatings, two eyepieces, finder, tabletop tripod, drive, case, and more! The 4000E lists for $980, but is **sale priced at $\$549^{00}$!**

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Compare prices on these B & L options.

Rich field adapter for all B & L	**$\$94^{50}$**
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At Ad-Libs Astronomics, we're now in our eighth year of saving you money on telescopes and accessories — and we're celebrating by extending our anniversary sale one more month! Just look at the bargains on this page!

These are all factory-fresh units, complete with *all* accessories supplied by the manufacturers. Unlike some so-called "discounters," we don't strip out standard accessories, claiming they're optional, just so we can show an artificially-low price. And we ship from stock better than 95% of the time. We don't use your money for two months while you wait in vain for your scope. Better yet, we don't charge up to $125 freight on a telescope, as some other "discounters" do. Our sale prices include *free freight* — even if you pay by credit card.

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Use our toll-free 800 number to order — or to get price quotes on any of the hundreds of products we carry . . . from Meade, Celestron, Edmund, TeleVue, Questar, Bausch & Lomb, Lumicon, Vernonscope, and more.

Remember, these sale prices, and our free freight offer, are only good through September 30 — so don't miss your chance to save!

Edmund Astroscan

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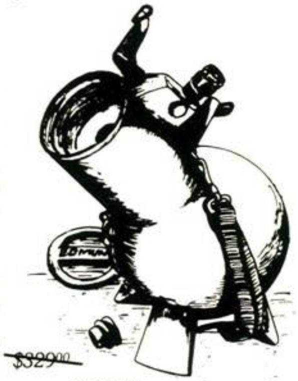

~~$\$329^{00}$~~

$269

2001 Astroscan

Here are some options for the Astroscan, too.

#2007 erecting prism, *$\$79^{95}$ list*	**$\$64^{95}$**
RKE eyepieces, *$\$32^{95}$ each list*	**$\$29^{95}$**
(Available in 8, 12, 15, 21, and 28mm.)	
RKE 2.5x Barlow, *$\$57^{95}$ list*	**$\$49^{95}$**
Tote bag, *$\$24^{95}$ list*	**$\$22^{95}$**

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The most completely integrated telescope systems available! Hand-matched, lazer-tested optics combine with quartz microelectronics to make these the world's most advanced Schmidt-Cassegrain telescopes. Orion is proud to offer these fine instruments in unbeatable packages which include Field Tripod, Equatorial Wedge, Declination Motor, Hand Control and much more. Call today for price and information!

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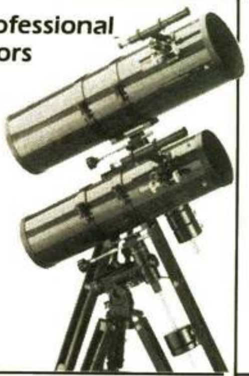

Ideal for a wide range of planetary and deep-sky astronomical observation. Compact, short tube precision Newtonian optical system on sturdy equatorial mounts with optional motor drive systems. Easily adapted for astrophotography. Call today for prices and details.

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Tri-pod not included

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Porta-Pac Rechargeable Energy Cell. The most convenient way to power your telescope in the field. Spill-proof, maintenance-free, and will last for years with normal use. Includes 117 volt charger. Capacity, 5.0 amp-hours, Maximum load, 15 watts. #2352 **$79.95**

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Our quality, affordable eyepieces for 1.25" eyepiece holders. Manufactured to strict tolerances. Chrome-plated brass barrels. MgFl anti-reflective coatings. Threaded for filters.

5mm Ortho #8471	**$46.95**	**18mm Kellner** #8466	**$28.95**
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Our catalog is packed with hundreds of accessories for the amateur astronomer. A small assortment is listed below.

Observer's Chair

Comfortable swivel-top padded stool with folding legs and adjustable height. A must for astrophotography. #5935 **$39.95**

Astronomer's Flashlight

Unique 45 degree angle flashlight made of unbreakable plastic has special night-vision red filter and a diffusion lens for even illumination. Includes belt clip, extra bulb. #5701 **$8.95**

Lightweight Dew Cap

For Celestron and Meade Schmidt-Cassegrain Telescopes Shields the corrector plate, offering two to four times longer viewing time. Mounts in seconds to your Celestron 8 or Meade 2080. High-quality black epoxy finish.
Celestron 8, #5181 **$49.95**
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Deluxe Eyepiece Case.

Designed to hold at least 10 eyepieces plus barlow. Die-cut foam insert, double-wall top, secure latch. 8-½×12-½×3-1/8. #5913 **$17.95**

Orion Deep Sky Binoculars

Superior unitized BCF body design. Fully coated optics. Center Focus with one ocular adjustment. All Orion Deep Sky Binoculars include lens caps, deluxe case, tripod mounting bracket and straps.

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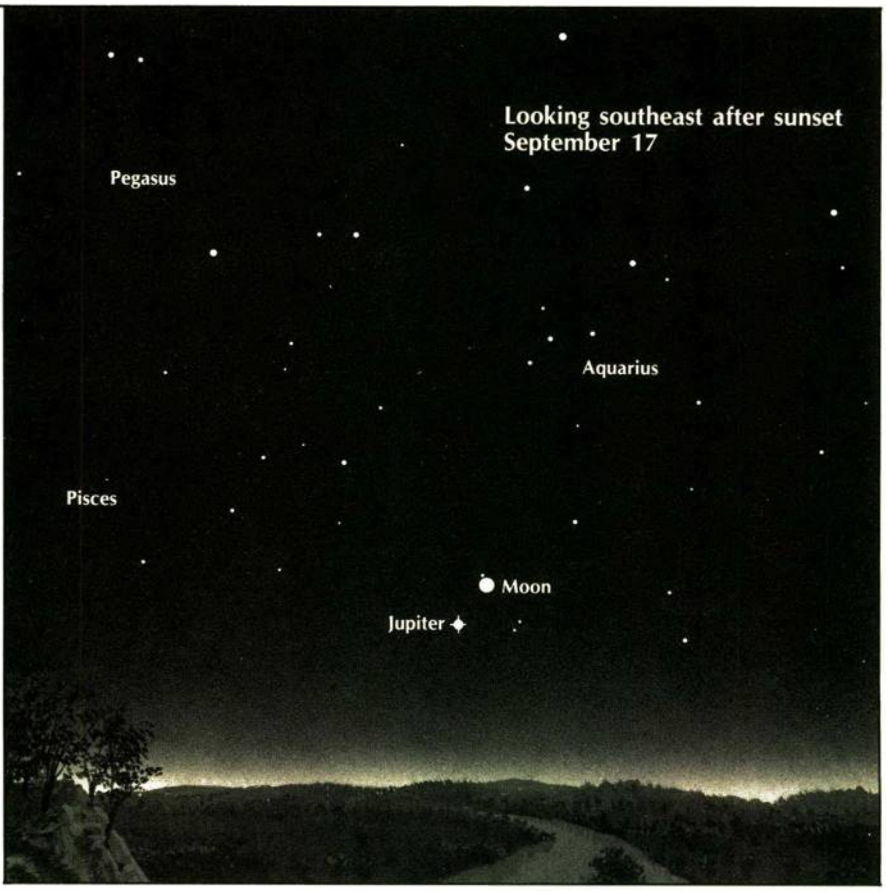
Venus Vanishes Into the Twilight

by Robert Burnham



The Wanderers

At the end of August and during the first half of September, the sky features several bright planets in the evening hours. Of these the most brilliant is also the lowest in elevation — **Venus**. Blazing-white at magnitude −4.5, Venus hovers low in the southwest as twilight darkens and sets about an hour and a half after the Sun. To get a good look at it you'll need a viewing site that offers a clear western horizon, such as a hilltop, ballfield, or large schoolyard.

Behind Venus lie the stars of the zodiacal constellation Virgo, though only 1st-magnitude Spica (which Venus lies close to on August 31) stands out in the twilight. On the 7th, the crescent Moon lies near Venus, having passed 3° north of it during the late afternoon hours.

Venus is almost at greatest brilliancy (−4.6 magnitude on October 1), but is dropping lower each day and becoming harder to see. Because of this, your best viewing opportunities will come in the first half of September.

As Venus sinks into the trees in the southwest, another bright planet is climbing into view in the southeast. Shining radiant white, **Jupiter** is at magnitude −2.9 this month, its brightest for the year. On September 10 the planet reaches opposition, the date when it lines up with the Earth and Sun and crosses the meridian at local midnight. To skywatchers this means Jupiter rises as the Sun sets and stays in view all night long.

Like Venus and the other planets, Jupiter's stellar "home" is one of the constellations along the zodiac or ecliptic. In Jupiter's case, the star group is Aquarius, near its border with Pisces. As both constellations are dim, though clearly visible away from city lights, Jupiter has little competition in brilliance from them.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Besides bright Jupiter and Venus, two other naked-eye planets are also in the evening sky: Mars and Saturn. **Saturn** shines ivory-white at magnitude 0.5. Since Saturn lies in Scorpius, dusk finds it low in the southwest, where it will set about three hours after the Sun.

Over the past months, Saturn has been near ruddy, 1st-magnitude Antares, the brightest star in Scorpius. But Antares is south of Saturn and therefore sets well before it. By October Saturn will be much harder to see.

Next to Scorpius along the ecliptic is Sagittarius, the star group currently providing the backdrop for **Mars**. At magnitude −1.3, Mars shines much brighter than its neighbor stars, and its warm ochre color also sets it apart.

During September Mars will move eastward away from the Teapot asterism of Sagittarius toward Capricornus. Though its movement won't be visible from one night to the next, a few days' observing will reveal distinct changes in position. This is especially easy to see near the beginning of the month, when Mars still lies close to the stars of the Teapot.

Of the remaining naked-eye planets, only **Mercury** remains unaccounted for. Technically it is in the evening sky after September 5, but this apparition is very poor. You'll do better to look for Mercury in the morning sky in November and December.

Top right: Comet Halley was photographed above the tree tops in Australia on April 22 by Rev. Ronald E. Royer using a 105mm lens, Fuji 1600D, and a 6-minute exposure.

Bottom right: This photo, made on April 7, shows Halley in the dawning sky above a strata of high clouds over the Anza-Barrego Desert in southern California. The bright glows are town lights. Fog can be seen hugging the low-lying areas in the distant mountains. Photograph by Jerry Schad.

This month and next are ideal, however, to look for a very elusive naked-eye phenomenon, the **zodiacal light**. Formed by sunlight glinting off billions of tiny particles of interplanetary dust, the zodiacal light is notoriously hard to see, except under a truly dark sky, when it becomes strikingly obvious.

On a cloud- and haze-free night during the first half of September (before Full Moon), drive to a location far away from city lights and look in the east during the last hour before morning twilight. The zodiacal light will be a soft pale glow in the shape of a triangle that extends upward from a base roughly 25° wide along the horizon to a point north of Orion. If you suspect that you see it, scan with your eyes back and forth across the region. If there's really any glow visible, you'll spot a brightening as you sweep past.

September Night Sky

New Moon
September 4
3:10 a.m. EDT

First Quarter
September 11
3:41 a.m. EDT

Full Moon
September 18
1:34 a.m. EDT

Last Quarter
September 25
11:17 p.m. EDT

1st Until about the 18th (the date of Full Moon), look for the zodiacal light in the eastern sky during the hour before morning twilight begins.

4th New Moon occurs at 3:10 a.m. EDT.

5th Mercury is at superior conjunction. It passes from the morning sky into the evening but won't be visible there until next month.

7th The Moon passes 3° south of −4.4-magnitude Venus in the evening sky.

10th The Moon passes 5° south of 0.5-magnitude Saturn in the evening sky. For viewers in Europe, Africa, and parts of Asia, the Moon occults the 1st-magnitude star Antares. Jupiter is at opposition, rising as the Sun sets, and is visible all night long. It shines at magnitude −2.9.

11th First Quarter Moon is at 3:41 a.m. EDT. The Moon is closest to Earth at 8:05 p.m. EDT: 229,754 miles.

13th The Moon lies near −1.4-magnitude Mars in the evening sky.

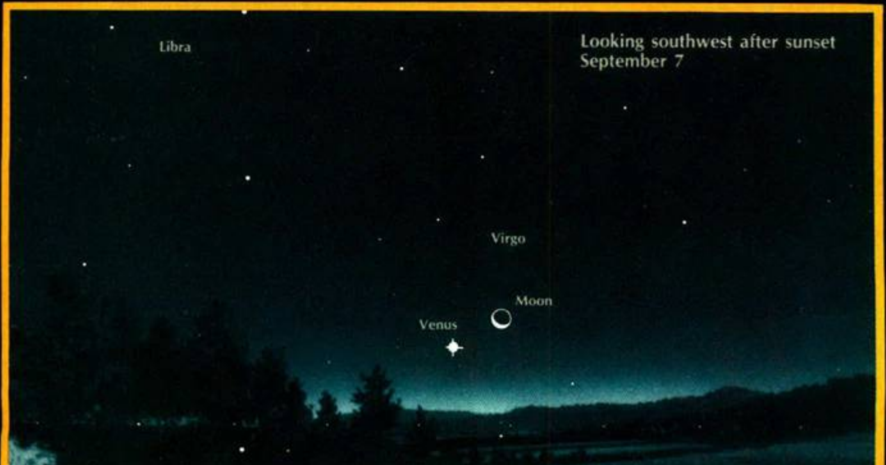
15th Around this time of the month, if you stay up until about 1 a.m., you can see the stars of summer sinking in the west while those of winter rise in the east.

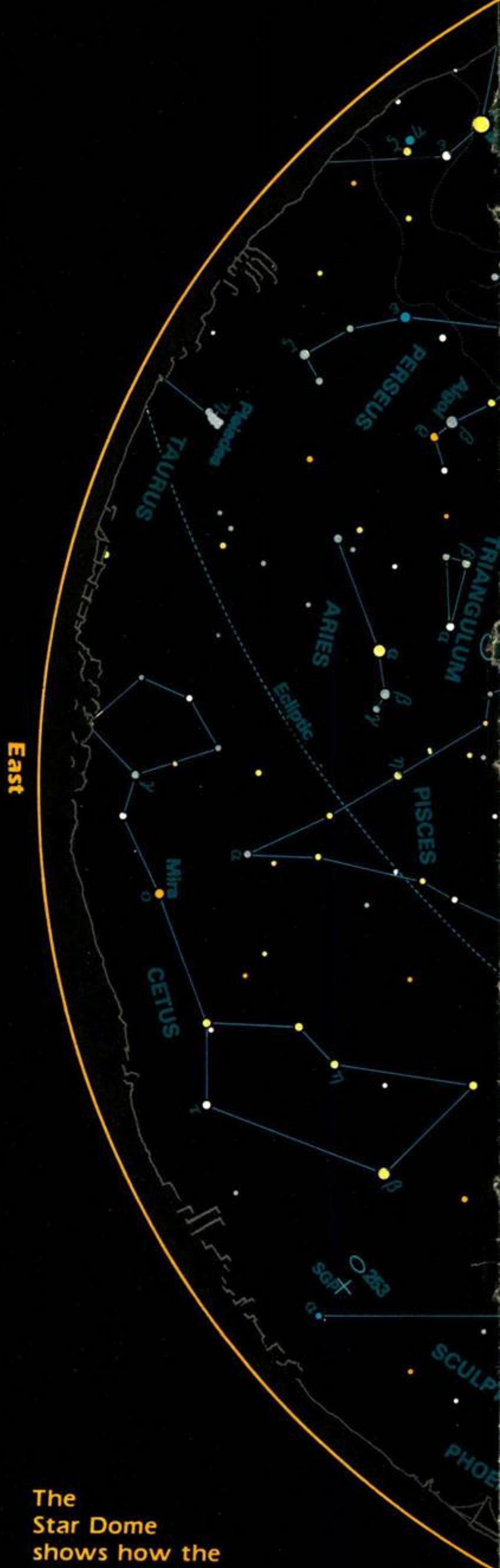
17th Halley's Comet is in conjunction with the Sun.

18th The Moon is Full at 1:34 a.m. EDT. This is the Harvest Moon.

23rd The Sun, moving southward, crosses the celestial equator at 3:50 a.m. EDT. This marks the autumnal equinox and the beginning of fall in the Northern Hemisphere.

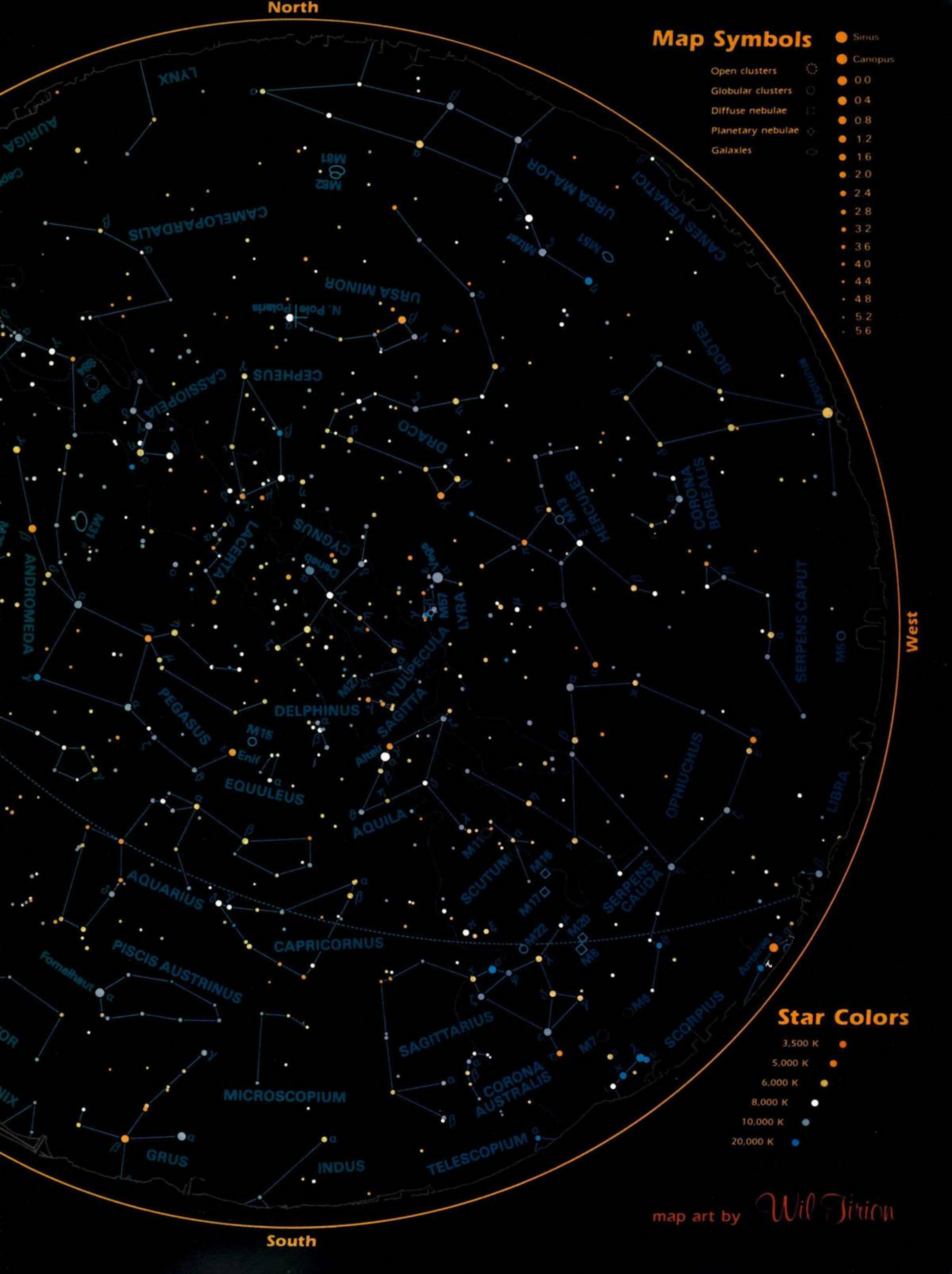
25th The Moon is farthest from Earth at 6:02 a.m. EDT: 251,241 miles. Last Quarter Moon occurs at 11:17 p.m. EDT. Mars is closest to the Sun.


Looking southwest after sunset
September 7



The
Star Dome
shows how the
sky looks at:

11:30 p.m. on September 1
10:30 p.m. on September 15
9:30 p.m. on September 30


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
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3.2
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5.6
LYNX
AURIGA
M81
M82
URSA MAJOR
CANES VENATICI
CAMELOPARDALIS
Mizar
M51
URSA MINOR
N. Pole Polaris
BOOTES
Arcturus
869
884
CASSIOPEIA
CEPHEUS
DRACO
M31
ANDROMEDA
LACERTA
CYGNUS
Deneb
Vega
M57
LYRA
M13
HERCULES
CORONA BOREALIS
SERPENS CAPUT
M5
West
VULPECULA
M27
DELPHINUS
SAGITTA
Altair
PEGASUS
M15
Enif
EQUULEUS
AQUILA
OPHIUCHUS
LIBRA
M11
SCUTUM
M16
M17
SERPENS CAUDA
AQUARIUS
CAPRICORNUS
M22
M20
M8
Antares
PISCIS AUSTRINUS
Fomalhaut
SAGITTARIUS
M6
M7
SCORPIUS
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
MICROSCOPIUM
CORONA AUSTRALIS
GRUS
INDUS
TELESCOPIUM
South

map art by Wil Tirion

The Starry Sky

Every fall a curious thing happens to the sky — the summer constellations refuse to go away! Long after they ought to vanish into the western twilight, summer's stars remain visible. Cygnus, for example, is first spotted in June evenings and can usually be seen well into November.

What's happening is that as night comes earlier each evening, it "turns off" the Sun a few minutes sooner. Thus the four-minute-per-day westward drift of the constellations, caused by Earth's orbital motion around the Sun, appears to be slowed significantly. (The inverse effect happens in spring, as the increasingly later sunsets hustle the winter constellations offstage.) Over the next three months watch how long the summer groups linger.

Nightfall finds the sky neatly bisected by the **Milky Way**, which spans the heavens from the southwest, where it is widest and brightest, to the northeast. Facing west, we see a few old friends from months past: **Bootes** the Herdsman, with Arcturus, and **Corona Borealis** the Northern Crown. Higher up is **Hercules**, whose torso is formed by four stars in a keystone shape. Hercules is upside down, with his head lying near **Ophiuchus** the Serpent Bearer. The Tail of the Serpent (**Serpens Cauda**) lies next to the Milky Way.

Scorpius the Scorpion, together with Saturn, have all but set; poised behind them is the Archer, **Sagittarius**, currently home base for Mars. It's worth sweeping the region between Sagittarius and Ophiuchus with binoculars to see the "Messier" objects (nebulae and star clusters) that lie there.

Up the Milky Way from Serpens we meet **Scutum** the Shield, and **Aquila** the Eagle. Aquila's brightest star is a white, 1st-magnitude gem named Altair. **Sagitta** the Arrow and **Vulpecula** the Fox fill the space between Aquila and **Cygnus** the Swan. Cygnus is sometimes called the Northern Cross, pairing it with Crux the Southern Cross, which is visible in March and April from latitudes south of 20° north. Deneb is the name of Cygnus' brightest star.

Between Cygnus and Hercules lies **Lyra** the Lyre, with brilliant Vega. Vega, Altair, and Deneb form an asterism called the Summer Triangle. Directly west of Lyra is the Head of the Dragon, **Draco**, whose body curls around **Ursa Minor** the Lesser Bear. Ursa Minor contains Polaris, the pole star. (Picking out the individual members of Draco, Ursa Minor, and many other constellations calls for a darker sky than most city dwellers have — an ideal excuse for a trip into the countryside during the dark of the Moon!)

On March 7, Halley hung high above a waning crescent Moon in the dull red morning sky over Oveido, Florida, making an excellent celestial composition. Photograph by Tim Printy using a 50mm, f/2 lens, Ektachrome 200, and a 15-second exposure.

Scanning along the Milky Way from Cygnus, we meet first dim **Lacerta** the Lizard and then the tall pentagon of **Cepheus**, a mythical king of Aethopia. The brightest star of Cepheus is named Alderamin, Arabic for "the right arm": In legend, Cepheus' Queen was **Cassiopeia**, whose star-group resembles a stretched letter M or W. The daughter of Cepheus and Cassiopeia was **Andromeda**, who is represented by the double line of stars springing away from the northeast corner of **Pegasus** the Flying Horse. Andromeda contains M-31, a galaxy similar in size to our own, which is 2.5 million light-years away. It is visible to the naked eye in a dark sky and is a pretty sight in binoculars.

We see Pegasus upside down; his body and wings form the Great Square (Alpha [α], Beta [β], Gamma [γ], and Alpha [α] Andromedae), while his arching neck and head stretch back toward the Milky Way to end at his nose, the star Enif. The Foal, **Equuleus**, and the Dolphin, **Delphinus**, lie between Enif and the Milky Way. Both are faint, but Delphinus's distinctive shape makes it fairly easy to spot even from city backyards.

These evenings the ecliptic reaches its greatest elevation in the southeast, where Jupiter stands guard between **Aquarius** the Water-Carrier and **Pisces** the Fishes. Westward from Aquarius lies the wide triangle of **Capricornus** the Sea-Goat. Pisces, Aquarius, and Capricornus are faint groups, requiring good dark skies for tracing them. Start at Jupiter and locate Alpha (α) Aquarii and the "Y" of four stars near it, then pick out the rest of Aquarius. Capricornus will follow pretty easily, as will Pisces once you get a sense of its size, which is larger than a star map may lead you to think.

Below Aquarius shines one lonely bright star, 1st-magnitude Fomalhaut, the luminary of **Piscis Austrinus** the Southern Fish. We'll explore this region in more detail next month.

Skylore

Many people know that September's Full Moon is called the Harvest Moon, yet few know what astronomical events spawned this special name.

A Full Moon — any Full Moon — occurs when the Moon lies 180° away from the Sun in the sky. In September, the month of the autumnal equinox, the Sun lies nearly on the celestial equator and, in celestial longitude, is close to the 12h meridian of right ascension. In terms of the ecliptic constellations, the Sun is in Virgo at the time of September's Full Moon. Since the Full Moon is in opposition to the Sun, it lies on the opposite side of the sky, also on the celestial equator but near the 0h meridian of right ascension. This location falls in the constellation of Pisces.

Since the Moon orbits the Earth once every 30 days (New Moon to New Moon), it glides eastward on the sky at an average rate of about 12° per day (360° divided by 30 days). Thus each day it lies 12° farther east and rises about 50 minutes later than the day before.

At this time of year, it happens that the ecliptic in Pisces makes a very shallow angle to the eastern horizon when it rises around the time of sunset. As the Moon rolls along in its orbit approaching Full, the normal course of things would cause it to rise about an hour later every night. But since the ecliptic roughly parallels the horizon this month, the 12° daily advance of the Moon doesn't translate into the ordinary delay in successive moonrise times. Instead of 50 minutes, the Moon rises only 20 minutes later each night.

Although most of us live in cities and pursue urban lifestyles, it doesn't take much imagination to see what a gift the Harvest Moon was for agricultural peoples. Every clear night for roughly a week, centered on the date of Full, a bright Moon would rise only a little later each evening and flood the fields with its light.

What, then, of the "Hunter's Moon" of October? In astronomical terms, it and the Harvest Moon are virtually the same. In October, the angle of the ecliptic isn't quite as shallow as in September, but the delay in rising still amounts to only some 25 minutes.

Besides these two well-known Moons, many other "Moons" have been named, chiefly from American Indian folklore. To the Indians, the sequence of named Full Moons served as markers for the lunar months of the year, much as the Moons in September or October do for us. In this tradition, February is the Hunger or Wolf Moon, July is the Thunder Moon, December is the Long Night Moon, and so on.

This month try a simple experiment. For several days before and after September 18, step outside around sunset and look eastward. There you'll see the rising Moon, yellowed by haze and looming very large. As you time its appearance each night, think back to your agricultural ancestors and enjoy this bit of natural daylight saving time.

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Galaxy M31 and small companion M-32 in Adromeda. Phot by Martin Germano using a LUMiCON Newtonian EASY-GUIDER^{TM}. 40 min. exposure using 103a-F film and an 8'' f/5 Newtonian telescope with LUMICON Helical Focuser.

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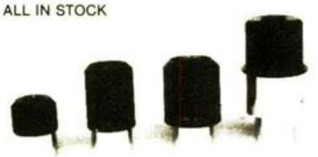

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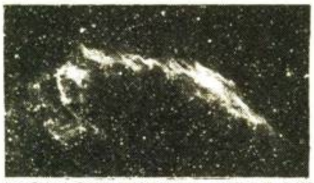

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Zepernick, Cresskill, NJ

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U.S. Patent 4,473,636

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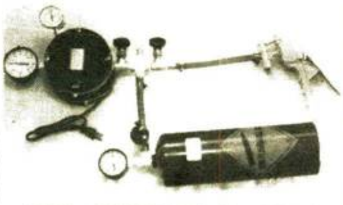

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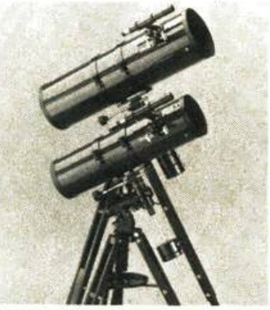

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Hunting Martian "Astroblemes"

Gazer's Gazette

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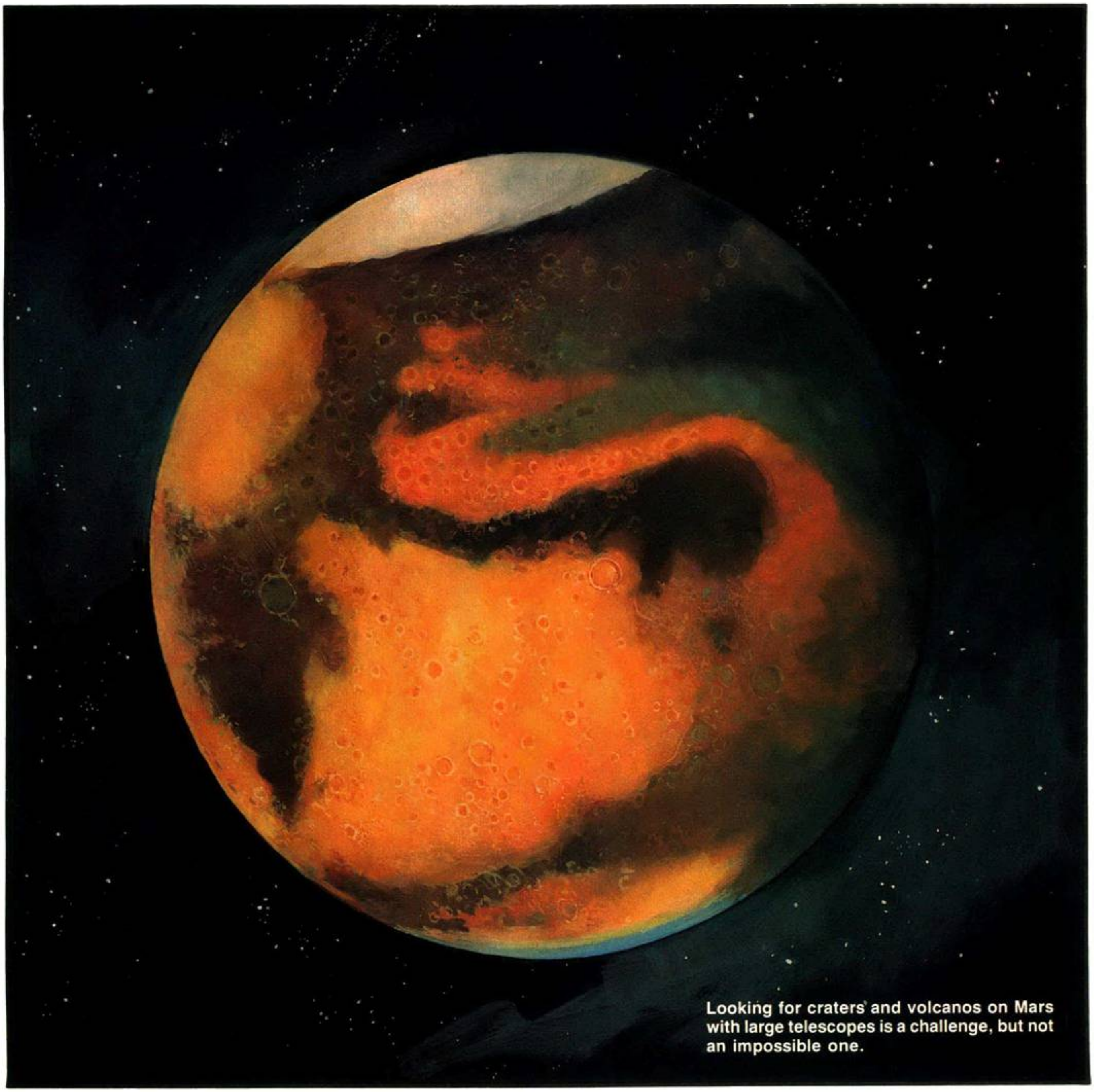


Looking for craters and volcanos on Mars with large telescopes is a challenge, but not an impossible one.

Barbara Ericksen

In an article published in the August 1961 issue of *Scientific American,* crater scientist Robert Dietz coined a word to describe terrestrial impact craters. He called them "astroblemes," from the Greek words meaning "star wounds." This also seems to be a good cognomen for large impact features found on the surfaces of other planets and moons.

Searching for astroblemes on Mars is good sport in medium-size telescopes (8- to 12-inch apertures) with focal ratios of at least f/6 when the planet is at or near opposition. During these times, Mars comes near enough to Earth that some of these features can just be discerned on its swollen disk. Fortunately, the images sent back by the Mariner and Viking probes have given credence to many of the astrobleme reports made by amateur observers both before and after the spacecraft encounters. But it is quite possible that many observers with medium-size telescopes have seen these subtle surface features without realizing what they were.

Years before our enlightenment by space probes, experienced planetary observers had reported seeing circular features, presumably craters, on Mars using large telescopes with high magnifications of 750x to 1,100x. The renowned lunar observer H. P. Wilkins, reporting in *The Smithsonian Report For 1956*, wrote, "When Mars was examined with the Yerkes 40-inch refractor, numerous canals were detected, and they all appeared to be uniform streaks strongly suggestive of cracks in the surface, while oases, several of which were seen, suggested craters, presumably filled up with some dark matter."

In 1966, comet observer and optician J. E. Mellish wrote, "The Mariner photographs taken last July reminded me of some observations of Mars that I made with the 40-inch refractor at Yerkes Observatory in 1916. Using a power of 1,100, I saw many small craters and one large one. The latter, estimated to be 200 miles in diameter, was in Martian latitude of -50°; north of it were many bright-rimmed small craters. After seeing the craters, I showed my pictures to E. E. Barnard, who in 1916 was on the staff of Yerkes Observatory. Opening an old trunk, he brought out drawings of Mars at opposition [in] 1892-93; on these, some craters appeared as dark circular patches."

Unfortunately, Mellish's collection of Mars drawings was lost in a fire in 1946, and the original disk drawings of Mars made by Barnard have never been located.

While patrolling Mars at opposition in May 1969 with the 82-inch reflector at McDonald Observatory in Texas, I encountered the best astronomical seeing conditions in thirty years of observing, and at a time when Mars was close to the Earth at opposition (with an apparent disk diameter of 19.3 arcseconds). The image

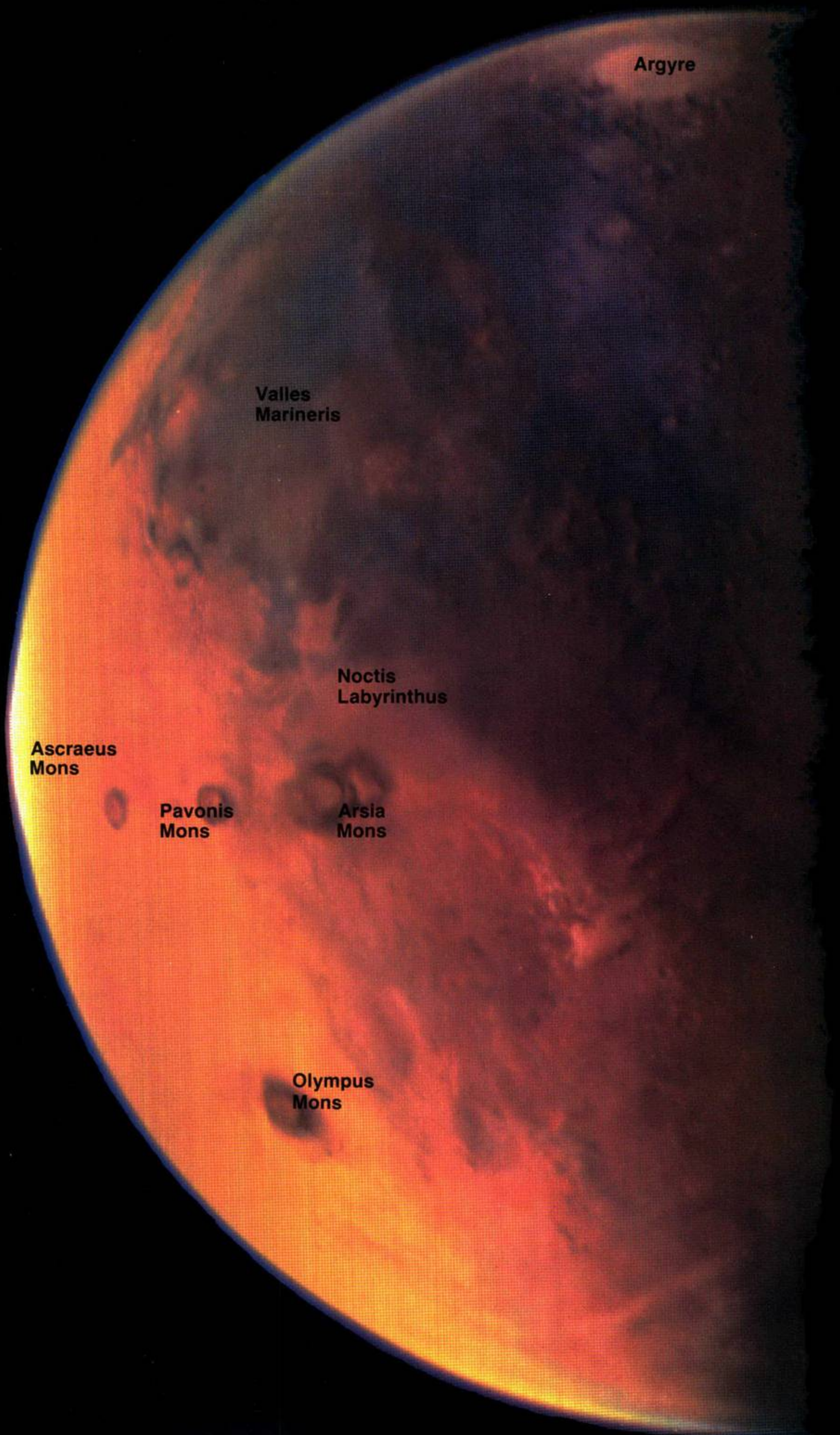
Some Martian Features For Large Telescopes

Another view of the region photographed by Viking 2 as the spacecraft approached Mars in August 1976. Note the white clouds extending from Ascraeus Mons. Pavonis Mons can just be seen in the dawn terminator. NASA/JPL photos.

Looking like dark blisters on the surface of the planet in this Viking 1 photo, Mars' four largest volcanos rise high above the Tharsis Ridge, a volcanic plain straddling the Martian equator. Extending upward (southeast) from the three aligned volcanos is the great canyon system Valles Marineris, which begins with the branched complex Noctis Labyrinthus just above Pavonis Mons. The basin Argyre is the bright region at the top of the photo.

Ascraeus Mons is the northernmost of the three aligned volcanos. It is 19 kilometers high and 370 kilometers in diameter. Pavonis Mons is the middle member and spans 340 kilometers. At the southwestern end of the chain is Arsia Mons.

Isolated from the others is Olympus Mons, the largest known mountain in the solar system. It rises some 25 kilometers above the Martian surface and has a base over 540 kilometers wide.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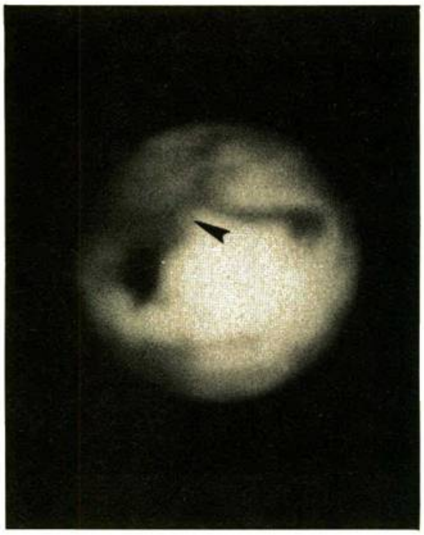
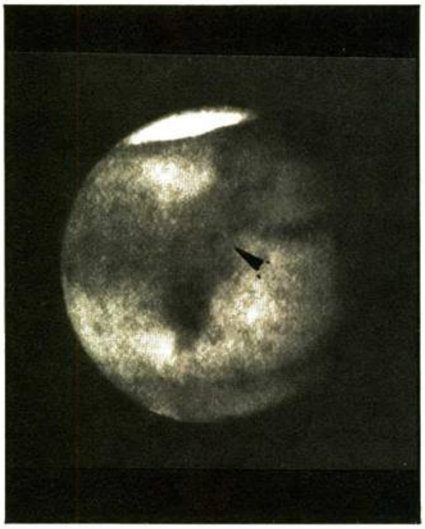
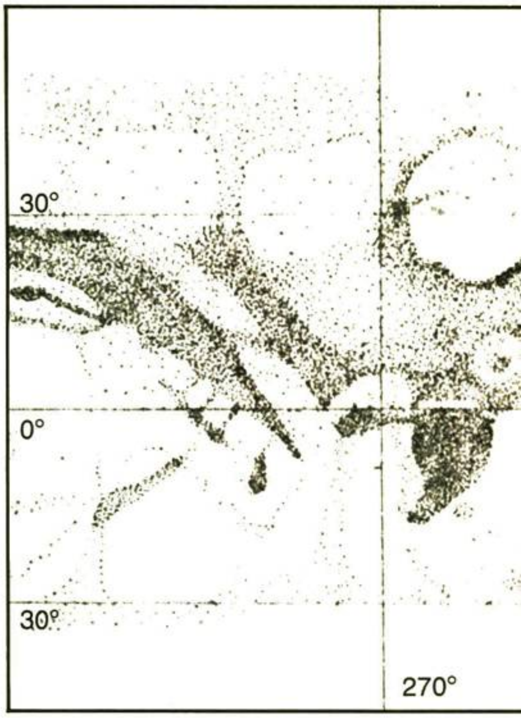






Left: Two photographs of Mars showing the large and semi-dark Huygens Crater, indicated by arrows. The top photo was taken in red light by Charles Capen at the coude' focus of the 82-inch reflector at McDonald Observatory on May 29, 1969. The bottom photo is frame 63 taken by Mariner 7 on August 2, 1969, at a range of 772,353 kilometers. The dark triangular feature left of center is Syrtis Major. NASA photos.

motion was often less than 0.1 arcseconds, which allowed definition of surface details smaller than 32 kilometers. On the nights of May 29, 30, and 31, Mars appeared to be draped in a dark gray spiderweb the shade and texture of iron filings. When 1,000x was employed, the global network of fine lines resolved into dark circular features and parallel streaks, some of which were fortuitously aligned into canal-like lineaments.

During the moments of good seeing, more fine surface details could be seen than could be recorded. Later, Mariner would identify many of these fine details as large craters and composites of dark blotches and streaks.

One feature in particular was apparent in photographs made with the 82-inch reflector: a circular area within the lapygia-Deltoton region located at 304° west longitude and 14° south latitude. Less than three months later, Mariner images revealed this to be a large, flat-floor crater, 8 areographic (Martian surface) degrees or 465 kilometers in diameter. In 1973, the IAU officially named this crater after Christiaan Huygens, the Dutch astronomer who, in 1659, was the first observer to sketch Syrtis Major, a prominent funnel-shaped mesa located to the northeast of the crater than bears his name.

Modern observers can take heart in the fact that Huygens used a 2⅓-inch telescope (with a 23-foot focal length!) to see a Martian surface feature with an areographic diameter of about 20° at its widest east-west dimension. Today, Syrtis Major is an obvious feature even in small astronomical telescopes. However, Huygens Crater spans about 8°, slightly less than half the size of Syrtis Major. Could a moderate-size telescope, in the 6- to 8-inch range, resolve it during good seeing?

In the August 1984 issue of the *Journal of the Associaton of Lunar and Planetary Observers*, observer Michael Mattei reported that he may have detected a large crater north of Hellas Basin in the lapygia-Deltoton region on September 14 and 16, 1973, with an Alvin Clark 6-inch refractor at 287x. His disk drawings showed a dark, circular spot, having high contrast, approximately 10° in diameter, and located at about 304° west longitude, 13° south latitude — practically at the same place on the Martian surface where I observed and photographed the Huygens astrobleme in May 1969.

These remarkable observations prompted me to make a few simple calculations to learn if it was possible to detect the dark crater with such a small telescope. The Dawes' Limit formula gives 0.75 arcseconds resolving power for a 6-inch telescope. Given an apparent disk diameter for Mars of 18.5 arcseconds and a total planetary surface diameter of 6,788 kilometers, a 6-inch scope should be able to resolve a dark spot near the center of the Martian disk as small as 4.6 areographic degrees, which is equivalent to a crater 275 kilometers across.

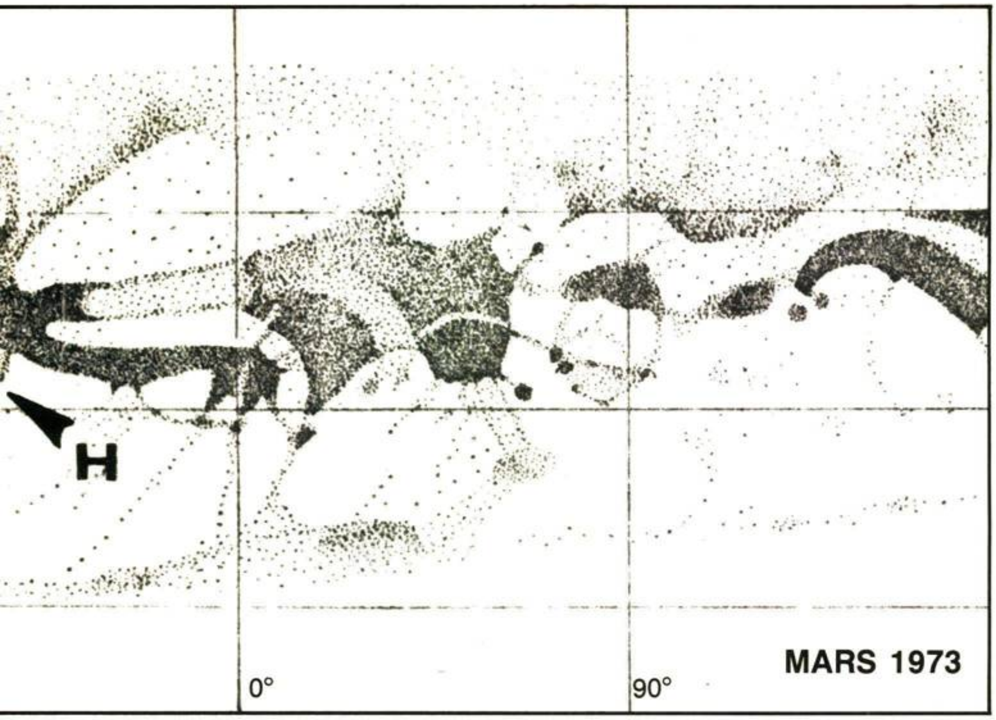
Of course, variable seeing conditions and the imperfections inherent in all optical systems rarely allow such resolution. However, a Martian crater the size of Huygens Crater (which would be slightly over 1 arcsecond in diameter on an 18.5-arcsecond disk) and located at 13° south latitude should be visible from Earth in a quality 6-inch, long focal-length telescope under excellent seeing conditions.

It is curious that Huygens Crater has not been discussed more often before Mattei called our attention to it, since the dark spot appears on a Mars chart and in photographs made by eight observers during the favorable perihelic Martian apparition in 1973.

Jean Dragesco, president of the Commission des Surfaces Planetaires (Planetary Surfaces Commission), described the feature in a 1973 article in the French astronomy periodical *L'Astronomie*: "Deltoton Sinus presented a curious aspect. Visual observations showed a confused light spot and all good photographs showed the existence of a circular, vague, light region, corresponding more or less with the circular area named Huygens, with a slightly eccentric dark central point."

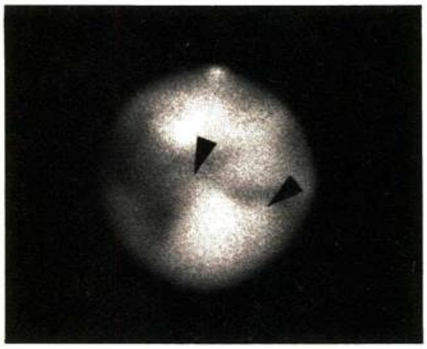
The planetary observer Tsuyoshi Arakawa photographed a small dark spot at the location of Huygens Crater on September 28, 1973, with an 8-inch Newtonian at Nara, Japan. On the nights of October 6, 8, and 10, the French astronomer Georges Viscardy photographed the same feature with a 20-inch reflector at Saint-Martin-de-Peille. On the nights of October 9 and 12, Spanish observers Luis Tomas and Jose Gomez, using a 15.5-inch Newtonian on the Isle of Teneriffe, photographed two dark spots: one was Crater Huygens and the other, located at about 290° west longitude and 20° south latitude, a region known as Depressio Ionica. As for this latter feature, the U.S. Geological Survey's *Atlas of Mars* shows a circular depression 2 kilometers deep. Planetary scientists believe this basin traps Martian dust.

Four American observers have likewise



Above: A 1973 planisphere of Mars drawn by Jean Dragesco showing a circular feature in the vicinity of the Huygens Crater. The chart was made from photographs and drawings by members of the Societe Astronomique de France.

Right: The Syrtis Major-Sinus Meridiani regions of Mars. Arrows indicate areas of Huygens Crater (left) and Schiaparelli Crater (right). Photo by Jim Rouse.



photographed both dark features within a month of each other in 1973. A. Sylvester used the Lowell Observatory Planetary Patrol 24-inch Cassegrain telescope, located on Mauna Kea volcano, on the night of September 22; E. Ken Owen of Oklahoma City used a 9.5-inch Newtonian on October 17; and J. Melka and R. Melvin of the McDonnell Douglas Astronomers in St. Louis used an 8-inch Newtonian during excellent seeing on October 19.

Apparently, the floor of Crater Huygens was very dark during September and October prior to the 1973 global dust storm that started within the "Eye-of-Mars," (Solis Lacus) half way around the planet. It is noteworthy that these two dark features were not observed during the next Martian opposition of 1975.

Listed below are several surface features that might be visible in 8- and 10-inch telescopes during good seeing. It is interesting to note that most of these were not correlated with actual topographic features until the Mariner and Viking missions. Bear in mind that telescopes with larger apertures (finer resolution) and long focal-lengths (larger image scale) are best suited for finding these subtle features. Always use high quality eyepieces and as much magnification as the image will stand without degrading. You might also try using filters for enhancing surface features, particularly the red Wratten 25A and magenta Wratten 30. (For more on observing Mars with filters, as well as a map of the major surface features, see Gazer's Gazette, June 1986.)

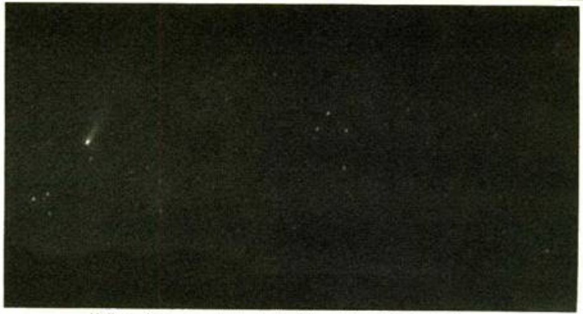
- Chryse Depression. Located about 20° northwest of Syrtis Major, this basin is 448 kilometers in diameter and is a region of dust storms.
- Valles Marineris. A dark-floor canyon system, 5,272 kilometers long, directly west of Margaritifer Sinus (which is similar in shape to Syrtis Major, but smaller). Look for bright ice-fogs and dust palls.
- Noctis Labyrinthus. A dark network of depressions and bright ice-fogs, extending west from Valles Marineris.
- Alba Patera. Located west of Mare Acidalium along west longitude 110° and north latitude 40°, this feature is a large volcanic shield, a gently sloping volcanic mountain built up by lava flows from a central vent.
- Ascraeus Mons. A 19-kilometer-high, 370-kilometer-wide dark volcano located at the northern end of a chain of three prominent volcanos straddling the Martian equator between west longitudes 100° and 140° in a region known as the Tharsis volcanic field. Like most of the volcanos on Mars, this one is associated with occasional bright white clouds.
- Pavonis Mons. The middle member of these three volcanos, located southwest of Ascraeus Mons, and about 340 kilometers in diameter.
- Arsia Mons. The southernmost volcano in this grouping, positioned just a little farther southwest of Pavonis Mons.
- Olympus Mons. With a 540-kilometer-wide base, Olympus Mons is the largest known volcano in the solar system. It is located northwest of the Tharsis Range volcano chain and nearly forms an isosceles triangle with the outer two volcanos, Arsia Mons and Ascraeus Mons, as vertices. It too is dark-hued and attracts white clouds.
- Ionica Depressio. A vast basin 2.5 kilometers deep and 870 kilometers wide, situated just southeast of Huygens.
- Cassini Crater. West of Syrtis Major at about north latitude 25° and west longitude 325°, Cassini is a 448-kilometer-wide crater with a dark floor and streaks.
- Schiaparelli Crater. A 500-kilometer-wide crater tucked in the nook formed at the juncture of Sinus Sabaeus and Sinus Meridiani.

Telescopic observation and space photography show that the albedos (or reflectivities) of many of these surface features vary daily and seasonally. Dark floors of valleys and canyons become filled with morning ice-fogs at certain times of the year. Crater floors can be filled with dark dune material, some of which may be deposited outside, leeward of the crater wall. Certain large, flat-floor craters become bright with frosts or dust-palls.

These changes in albedo help bring out the contrast in topographic features. Several circular and aligned relief features are large enough to be seen in telescopes with apertures of 8 inches or more during moments of good seeing, especially if their contrasts are enhanced with dark deposits or bright ice deposits.

Although looking for these elusive features is not easy work, consider them a challenge to your instrument and observing skills. Good hunting!

Charles Capen, internationally known planetary astronomer, veteran Mars observer, and official Mars recorder for the Association of Lunar and Planetary Observers, died at his home in Cuba, Missouri, on May 29. Mr. Capen was a frequent contributor to ASTRONOMY since its inception in 1973. His most recent article, "Observing Halley's Comet with Color Filters," appeared in the March 1986 issue.



Halley rises over Haleakala, Planet Earth's third highest mountain. Canon 4SB Rngfdr, w/Nikkor f/1.4 50mm, Fuji 1600, 20 secs. Guardrail mount, March 7, 1986, Island of Maui.

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*New Horizons Newsletter", Winter 1985, Pensacola, Florida, 32504.

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***See SKY AND TELESCOPE, June 1985.

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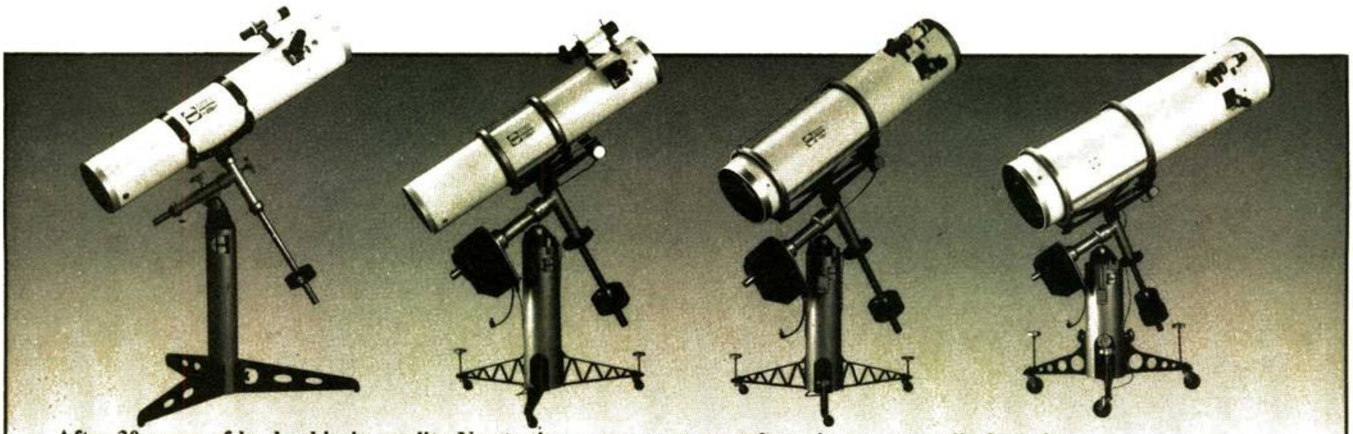

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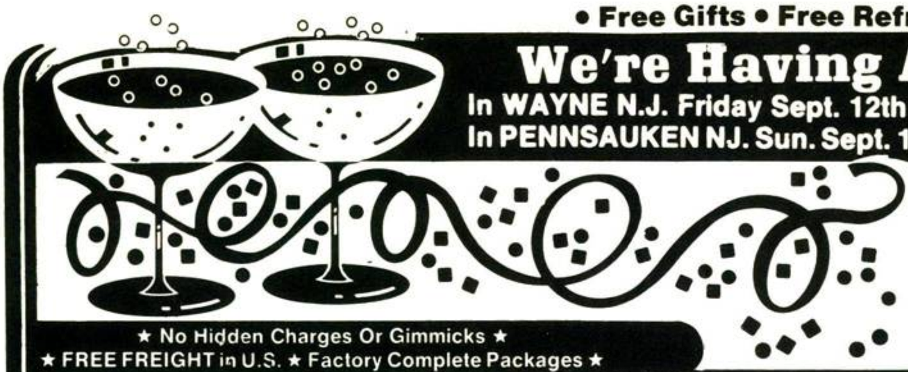

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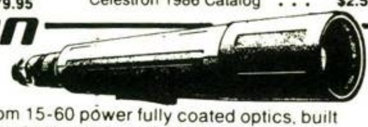

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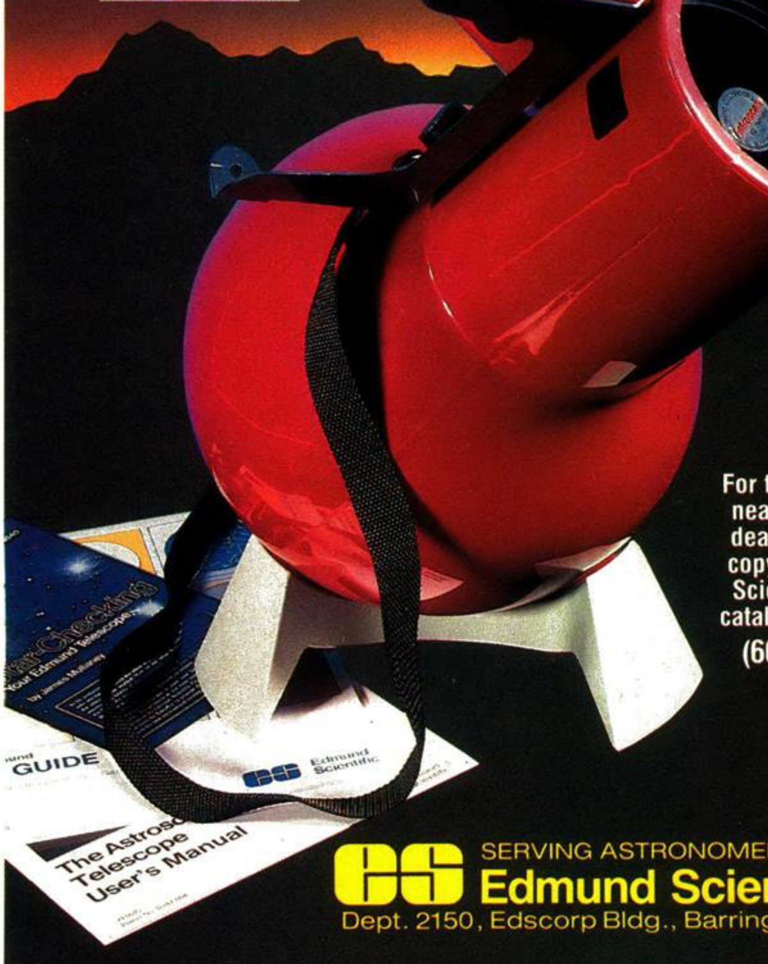
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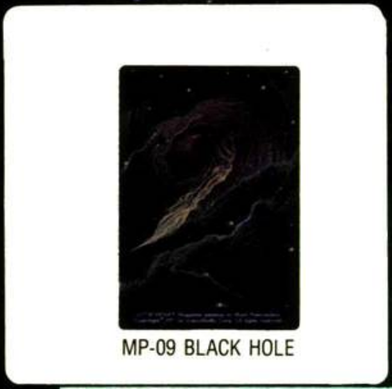

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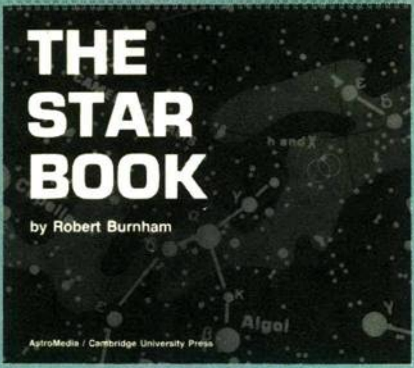

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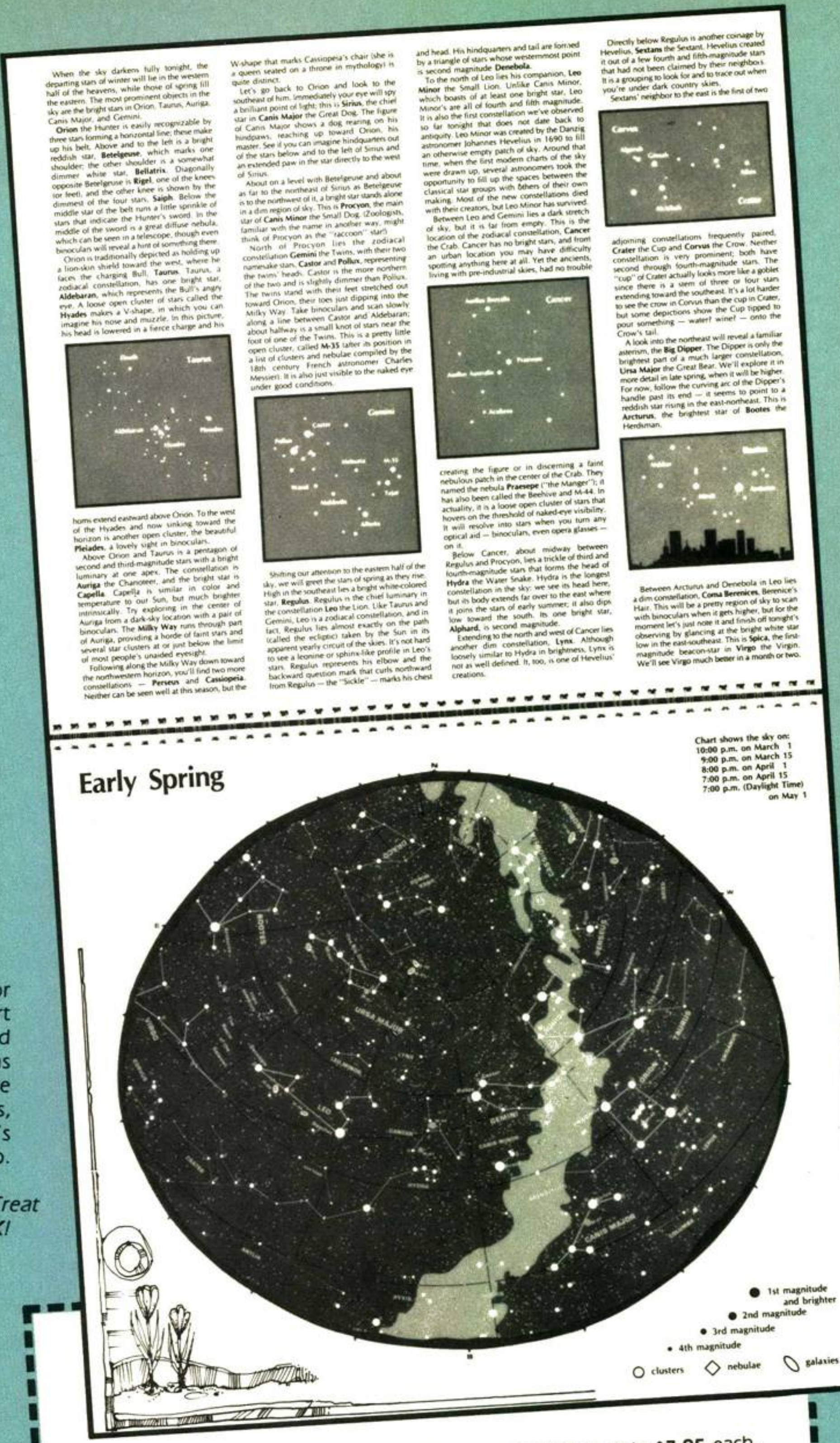

When the sky darkens fully tonight, the departing stars of winter will lie in the western half of the heavens, while those of spring fill the eastern. The most prominent objects in the sky are the bright stars in Orion, Taurus, Auriga, Canis Major, and Gemini.

Orion the Hunter is easily recognizable by three stars forming a horizontal line; these make up his belt. Above and to the left is a bright reddish star, **Betelgeuse**, which marks one shoulder; the other shoulder is a somewhat dimmer white star, **Bellatrix**. Diagonally opposite Betelgeuse is **Rigel**, one of the knees (or feet), and the other knee is shown by the dimmest of the four stars, **Saiph**. Below the middle star of the belt runs a little sprinkle of stars that indicate the Hunter's sword. In the middle of the sword is a great diffuse nebula, which can be seen in a telescope, though even binoculars will reveal a hint of something there.

Orion is traditionally depicted as holding up a lion-skin shield toward the west, where he faces the charging Bull, **Taurus**. Taurus, a zodiacal constellation, has one bright star, **Aldebaran**, which represents the Bull's angry eye. A loose open cluster of stars called the **Hyades** makes a V-shape, in which you can imagine his nose and muzzle. In this picture, his head is lowered in a fierce charge and his horns extend eastward above Orion. To the west of the Hyades and now sinking toward the horizon is another open cluster, the beautiful **Pleiades**, a lovely sight in binoculars.

Above Orion and Taurus is a pentagon of second and third-magnitude stars with a bright luminary at one apex. The constellation is **Auriga** the Charioteer, and the bright star is **Capella**. Capella is similar in color and temperature to our Sun, but much brighter intrinsically. Try exploring in the center of Auriga from a dark-sky location with a pair of binoculars. The **Milky Way** runs through part of Auriga, providing a horde of faint stars and several star clusters at or just below the limit of most people's unaided eyesight.

Following along the Milky Way down toward the northwestern horizon, you'll find two more constellations — **Perseus** and **Cassiopeia**. Neither can be seen well at this season, but the W-shape that marks Cassiopeia's chair (she is a queen seated on a throne in mythology) is quite distinct.

Let's go back to Orion and look to the southeast of him. Immediately your eye will spy a brilliant point of light; this is **Sirius**, the chief star in **Canis Major** the Great Dog. The figure of Canis Major shows a dog rearing on his hindpaws, reaching up toward Orion, his master. See if you can imagine hindquarters out of the stars below and to the left of Sirius and an extended paw in the star directly to the west of Sirius.

About on a level with Betelgeuse and about as far to the northeast of Sirius as Betelgeuse is to the northwest of it, a bright star stands alone in a dim region of sky. This is **Procyon**, the main star of **Canis Minor** the Small Dog. (Zoologists, familiar with the name in another way, might think of Procyon as the "raccoon" star!)

North of Procyon lies the zodiacal constellation **Gemini** the Twins, with their two namesake stars, **Castor** and **Pollux**, representing the twins' heads. Castor is the more northern of the two and is slightly dimmer than Pollux. The twins stand with their feet stretched out toward Orion, their toes just dipping into the Milky Way. Take binoculars and scan slowly along a line between Castor and Aldebaran; about halfway is a small knot of stars near the foot of one of the Twins. This is a pretty little open cluster, called **M-35** (after its position in a list of clusters and nebulae compiled by the 18th century French astronomer Charles Messier). It is also just visible to the naked eye under good conditions.

Shifting our attention to the eastern half of the sky, we will greet the stars of spring as they rise. High in the southeast lies a bright white-colored star, **Regulus**. Regulus is the chief luminary in the constellation **Leo** the Lion. Like Taurus and Gemini, Leo is a zodiacal constellation, and in fact, Regulus lies almost exactly on the path (called the ecliptic) taken by the Sun in its apparent yearly circuit of the skies. It's not hard to see a leonine or sphinx-like profile in Leo's stars. Regulus represents his elbow and the backward question mark that curls northward from Regulus — the "Sickle" — marks his chest and head. His hindquarters and tail are formed by a triangle of stars whose westernmost point is second magnitude **Denebola**.

To the north of Leo lies his companion, **Leo Minor** the Small Lion. Unlike Canis Minor, which boasts of at least one bright star, Leo Minor's are all of fourth and fifth magnitude. It is also the first constellation we've observed so far tonight that does not date back to antiquity. Leo Minor was created by the Danzig astronomer Johannes Hevelius in 1690 to fill an otherwise empty patch of sky. Around that time, when the first modern charts of the sky were drawn up, several astronomers took the opportunity to fill up the spaces between the classical star groups with others of their own making. Most of the new constellations died with their creators, but Leo Minor has survived.

Between Leo and Gemini lies a dark stretch of sky, but it is far from empty. This is the location of the zodiacal constellation, **Cancer** the Crab. Cancer has no bright stars, and from an urban location you may have difficulty spotting anything here at all. Yet the ancients, living with pre-industrial skies, had no trouble creating the figure or in discerning a faint nebulous patch in the center of the Crab. They named the nebula **Praesepe** ("the Manger"); it has also been called the Beehive and M-44. In actuality, it is a loose open cluster of stars that hovers on the threshold of naked-eye visibility. It will resolve into stars when you turn any optical aid — binoculars, even opera glasses — on it.

Below Cancer, about midway between Regulus and Procyon, lies a trickle of third and fourth-magnitude stars that forms the head of **Hydra** the Water Snake. Hydra is the longest constellation in the sky: we see its head here, but its body extends far over to the east where it joins the stars of early summer; it also dips low toward the south. Its one bright star, **Alphard**, is second magnitude.

Extending to the north and west of Cancer lies another dim constellation, **Lynx**. Although loosely similar to Hydra in brightness, Lynx is not as well defined. It, too, is one of Hevelius' creations.

Directly below Regulus is another coinage by Hevelius, **Sextans** the Sextant. Hevelius created it out of a few fourth and fifth-magnitude stars that had not been claimed by their neighbors. It is a grouping to look for and to trace out when you're under dark country skies.

Sextans' neighbor to the east is the first of two adjoining constellations frequently paired, **Crater** the Cup and **Corvus** the Crow. Neither constellation is very prominent; both have second through fourth-magnitude stars. The "cup" of Crater actually looks more like a goblet since there is a stem of three or four stars extending toward the southeast. It's a lot harder to see the crow in Corvus than the cup in Crater, but some depictions show the Cup tipped to pour something — water? wine? — onto the Crow's tail.

A look into the northeast will reveal a familiar asterism, the **Big Dipper**. The Dipper is only the brightest part of a much larger constellation, **Ursa Major** the Great Bear. We'll explore it in more detail in late spring, when it will be higher. For now, follow the curving arc of the Dipper's handle past its end — it seems to point to a reddish star rising in the east-northeast. This is **Arcturus**, the brightest star of **Bootes** the Herdsman.

Between Arcturus and Denebola in Leo lies a dim constellation, **Coma Berenices**, Berenice's Hair. This will be a pretty region of sky to scan with binoculars when it gets higher, but for the moment let's just note it and finish off tonight's observing by glancing at the bright white star low in the east-southeast. This is **Spica**, the first-magnitude beacon-star in **Virgo** the Virgin. We'll see Virgo much better in a month or two.

Early Spring

Chart shows the sky on:
10:00 p.m. on March 1
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Reviews

Guide to Observing the Moon
British Astronomical Association
128 pages, cloth, $14.95
Enslow (1986)
[publisher's address: Box 777, Hillside, NJ 07205]

What should a contemporary guide to observing the Moon contain? Up until about two decades ago, the prescription for such a work was straightforward, if challenging to carry out. Basically, lunar observers needed a carefully detailed map and extensive descriptions of the features that noted heights of crater rims, depths of crater floors, patterns of rilles, cliffs, chains of craterlets, and so on.

From this formula came the great classics of English selenography, each titled simply *The Moon*, by Edmund Neison (1876), Thomas Gwyn Elger (1895), Walter Goodacre (1931), and H. Percy Wilkins and Patrick Moore (1955). Long out of print, these works still command high prices on the used-book market.

But the heyday of the encyclopedias of topography is gone. Today, you can't comfortably combine a tour of the lunar terrain visible in your backyard telescope with an up-to-date account of lunar science; the gap is too wide. Although amateur astronomers once had a significant role in lunar research, new insights in lunar science now come from studies of isotope ratios in the Apollo and Lunakhod samples — hardly a backyard enterprise.

As a result, about twenty years ago amateur Moon observing began to split in two. The path most observers took emphasized plain "looking." Night after night, you would train your scope on the Moon, following the advance of the terminator as it splashed the rugged landscape with whitewash and ink. In your imagination you traveled there — and if you wished hard enough the eyepiece of your telescope became the porthole of a spaceship, cruising high over the Moon.

For such observers, the golden era of selenography has yet to end. The lunar descriptions of Elger and Neison are still as good as they ever were. (In the same way, the original visual observations of nebulae by William and John Herschel that went into the NGC are being rediscovered by today's deep-sky observers, who are often equipped with telescopes of similar aperture.)

But what about the other path? Although the "sightseers" far outnumber them, a small group of dedicated observers continues the amateur scientist tradition. With perfect truth, they point out that while poking around in the highland breccias is essential for understanding the Moon's history, no professional lunar scientist is keeping an eye on the big picture. Moreover, many terrestrial observers have reported seeing anomalous brightenings, color changes, and obscurations in certain lunar features, such as Aristarchus, Plato, Alphonsus, and a number of others. These events are still not understood.

The British Astronomical Association's Guide is clearly written for the latter group of Moon-watchers. It is an anthology of individually authored chapters. You'll find nothing in here on lunar geology or the old debate on the origin of craters. To judge by its contents, the intended reader is someone with a desire to make useful observations of the Moon, but who may not even own a telescope.

Chapter 1 describes the Lunar Section of the B.A.A., discussing its current programs and outlining its glorious past history. (Elger, Goodacre, Wilkins, and Moore each directed it at one time or another.) Chapter 2 covers equipment and makes the sensible recommendation that you buy the largest scope you can afford *that has a stable mounting.*

With Chapter 3, I ran into an organizational problem. The chapter is supposed to introduce the reader to exploring the Moon but it assumes that the reader knows material that is not presented until Chapters 4 and 5. This kind of mixup happens easily in a multi-author work, but where was the editor?

Chapter 6 covers drawing lunar features, a subject many shy away from, thinking that it requires great artistic ability. The three authors (one an architect) tell how easy and inexpensive it is to get started and show some fine examples of crater drawings.

Chapter 7 is on lunar photography. It offers formulae for calculating effective focal length (and f/ratio) and mentions some practical hints, finishing with the comment that trial and error, carefully tracked with a logbook, will teach you the most. Trial and error is a great teacher, but I think neophyte lunar photographers could save a lot of film by first reading over a few standard works on astrophotography to get background that the *Guide* doesn't provide. Chapter 8 covers photographing a lunar eclipse and offers much good advice, ranging from planning your shots ahead of time and being well-versed in the use of your equipment to recommended exposures for various stages of the eclipse.

Chapter 9 is on "transient lunar phenomena" or TLPs (which are called LTPs in the U.S.), those mysterious brightenings and colorations mentioned above. If these are real — caused perhaps by outgassing — then something of significance is being overlooked by the professionals. The problem is that observing them calls for experience and luck. Few professionals are willing to spend hours glued to an eyepiece, looking at this feature or that through colored filters while hoping to spot an enhanced brightening. So, for lack of data, the verdict on TLPs remains uncertain. And it is likely that here amateurs still have real, scientifically valuable work to do.

Chapter 10 covers observing occultations; Chapter 11 deals with making studies of lunar formations at all Sun angles; and Chapter 12 is a technical one on photometric and colorimetric properties of the lunar surface. The book closes with a bibliography (unfortunately, it is incomplete, very out of date, and short), three appendices (numerical data on the Moon, a list of lunar probes, and a Moon map), and an index. Of the appended matter, the map is easily the best of the lot; it identifies most features that you can pick out with a 4- to 6-inch telescope at medium power.

I'd like to be more enthusiastic about this book, but I think that in focusing on "useful work" it misses a large potential audience. Its unspoken assumption seems to be that casual observing — the mental astronautics I mentioned before — is time gone to waste. By thus focusing on a narrow, special approach that relatively few Moon watchers are interested in, at least in the U.S., the book necessarily limits its appeal.

Secondly, I found the *Guide* often inadequate, even on its own terms. Its organization is poor, with the chapters reading best in the sequence 1, 2, 4, 5, 3, 6, 11, 10, 9, 7, and 8. (I would drop Chapter 12 as too specialized and technical, place photography last since it requires expensive extra equipment, and leave the primary emphasis on straightforward visual observations.) In addition — and this is a serious omission for North American readers — there is no mention whatever of the Association of Lunar and Planetary Observers or its programs. Although not performing the same function as the B.A.A., the A.L.P.O. has an active lunar section and deals with every area of solar system observing. Ignoring A.L.P.O: is a first-class *faux pas*.

In sum, I can't recommend the book, though I do hope that it survives to correct its drawbacks in a second edition. It unquestionably fills a hole in the observing literature, but one wishes it did so far better. *Robert Burnham.*

Webb Society Deep Sky Observer's Handbook, Double Stars, 2nd edition

Robert Argyle
192 pp., paper, $13.95
Enslow Publishers (1986)

The second edition of England's Webb Society's double star observing guide is an updated and slightly expanded version of the first edition published ten years ago. It is the first of a five-volume series covering deep-sky objects that is intended to serve as an introduction for novices to double star observing and as a reference manual for more experienced observers.

The book begins with an outline of the history of double star observing, highlighting many prominent double star observers along the way, including the Herschels and the Struves, Burnham, Aitken, Finsen, Rossiter, and others. The first chapter deals mainly with the progress of discovery, measurement, and cataloguing of pairs and concludes with a brief summary of current double star research at observatories worldwide.

The next chapter discusses the types of double stars (orbiting, spectroscopic binaries, optical pairs) and their orbits. The fundamental task facing double star astronomers is determining their orbits. In combination with photometry, spectral classification, and measurement of radial velocity, parallax, and proper motions, a double star's orbit provides information about the stars in it.

A long-standing gap in our knowledge, for instance, has been determining the masses of individual stars of various temperatures and intrinsic brightnesses. Probably our only direct measurement of the mass of any star other than the Sun will come from observations of double stars. Although the orbital elements of pairs are described in the book, nothing is said of actual orbit determination, and no reference is made to books that do cover the topic.

Two chapters on amateur observing techniques go into some detail about the limits of resolution of any given telescope, which are the result of the wave nature of light, diffraction phenomena, and the shapes of telescopic apertures. Direct visual methods are discussed, as well as photography (briefly), micrometry, and observations of lunar occultations.

Photography of doubles is covered more thoroughly in a separate chapter. Since easily photographable pairs tend to be bright, exposures are short, as in planetary photography. Good seeing and precision focus are musts. While the photographic process and the special technique of shooting doubles are discussed adequately, readers are left to figure out for themselves how to measure the images once obtained and to stumble over other confusing pitfalls.

A long chapter gets down to the literal nuts and bolts of constructing micrometers to measure double star separations and orientations. The instrument of choice among the few professionals still engaged in this sort of work is the filar micrometer. These are difficult to make, however, and the commercially available models are expensive. (Small-run manufacturers are located in the U.S. and the U.K.) For the telescope maker, the author suggests constructing one or another type of micrometer using prisms. However, the prisms in these devices can be expensive, and fabricating them to be usefully accurate requires some real metal-working skill.

For those of us who are all thumbs or are on tight budgets, a diffraction micrometer is strongly recommended as a starter. This consists merely of a series of broad slits, called a grating, placed over a telescope's aperture that rotates with respect to a calibrated scale. While the results are not of high precision, it works and it's cheap. It is also a light-waster, as roughly half the telescope's aperture is covered by the grating bars.

The second half of the book is a catalogue of double stars. The list here is not much longer than in the first edition — 685 star systems. The selection includes objects ranging from very easy (resolvable in low-power binoculars) to quite difficult pairs that are challenging for any aperture.

Unfortunately the list is not comprehensive. It would be handy, for instance, to have a list of all pairs brighter than 6th magnitude and wider than one arcsecond (up to, say, 20 arcseconds, just to keep things interesting). Six Webb Society members contributed a few measures of the stars, but 70 percent of the results tabulated here were obtained by just one person: Maurice Duruy, an active French amateur who died in 1984.

Readers of this book who are unfamiliar with the literature of double star astronomy are likely to accept the measures given in the catalogue as gospel. This would be a mistake. They are only data gathered by the contributors, untempered by "definitive" seasonal averages obtained by combining the results of many good observers. Thus I was able to find pairs with orbits that show them to be closing, yet the Webb Society data for the same interval indicate just the opposite.

Luckily, the individual measures are followed by an extensive section of notes that includes essential ADS numbers (referring to the much-used Aitken double star catalogue) and information about the motion of orbiting pairs. An improvement would have been to provide ephemerides for well-known pairs or at least positions for dates a few years in advance. (Only those for 1985 are given, which were out-of-date before the book was published.)

I was pleased that an effort was made by the Webb Society and Enslow Publishers toward making the book's layout presentable. A near-fatal flaw of all the first five volumes was the use of tacky printing directly from typescript, with occasional lines done on a second typewriter and pasted in at a slant! The typescript has been retained here, but the work is now at least uniform, neat, and relatively free of errors. *Brian Skiff.*

The Night Sky

Ian Ridpath and Wil Tirion
240 pages, paper, $4.95
Collins (1985)

I don't suppose there's any such thing as the perfect star atlas. At least, I've yet to see one.

If the atlas is small enough to be carried easily, like *Norton's*, then the charts don't include everything you can see with your scope. And if the charts are big enough to include lots of detail, the page is awkward to use, prone to ripping, and hard to consult under the dim glow of a red-lensed flashlight.

The so-called field-guide star atlases attempt a solution. These are less expensive and generally quite pocketable, but in trying to provide most of the data of a full-sized star atlas, the field guides' charts are usually far too crowded. The top award for "data density" surely goes to Wil Tirion's charts in the Menzel/Pasachoff *Field Guide to the Stars and Planets* (Houghton Mifflin, 1983). These are a cartographic marvel, but using them under field conditions isn't easy.

The Night Sky offers a sensible compromise. It's neither a full-blown star atlas nor a field guide to all of astronomy. Instead, your $5 buys a set of eighty-eight constellation charts, one for each group in the IAU canon. The charts plot all stars down to magnitude 5.5. Since this is the naked-eye limit for most people under an excellent dark sky, the charts are ideal for naked-eye and binocular gazing.

The charts are supplemented with several that show areas of special interest at magnified scale and with deeper magnitude limits. For example, a special chart details the region of the galactic center and shows stars down to 7th magnitude. Two others show the Hyades and Pleiades fields down to 8th magnitude and label all the stars that have common designations. Another traces the movement of Barnard's Star in Ophiuchus, the star with the largest known proper motion, and another details the "Coathanger" asterism in Vulpecula.

The typical constellation chart shows the featured group in the center of the page; the sky background is medium blue, with the Milky Way shown in a lighter blue. (Each color becomes a different shade of gray under red light.) A thin white line traces the official constellation border while thin black lines show the meridians and parallels of right ascension and declination; the ecliptic is a dashed black line. Adjoining constellations are labeled and their stars are shown.

Stars appear as white dots graded in size by magnitude; variable stars have two concentric circles that represent the magnitude at maximum and minimum light. Nonstellar objects are coded with the same symbols Tirion used in his *Sky Atlas 2000.0.* Directly opposite each constellation chart is a brief text that outlines the constellation's history and describes its main features. Under red light, the stars "pop" nicely from the background and all the information on the chart is readable.

Placing the constellations in their proper relationship to each other, there is a 10-page all-sky chart with stars to magnitude 4.5 at the beginning of the book. This is coupled to an introduction that explains star names and designations, brightnesses, colors, distances, variable stars, clusters, nebulae, and galaxies. An index includes all named objects, including the M and NGC objects.

Ridpath and Tirion collaborated before on a field guide that covered all of astronomy, the *Universe Guide to Stars and Planets* (Universe Books, 1984). The star charts in this new book are substantially different — and better. For one thing, a few more deep-sky objects have been added to the new charts. Second, the object labels, being black type on the blue sky background, don't clamor for attention as the white labels did in the older guide. (The same goes for the RA and Dec. lines, white in the older guide.) Whereas the old charts looked "busy", the new ones carefully discriminate between levels of information and present them appropriately. The charts in *The Night Sky* are examples of clarity that every celestial cartographer should study.

Physically, the book is pleasing to handle. It measures just 3½ by 4⅝ inches and is half an inch thick; it slips easily into even a small shirt pocket. Moreover, although it is a paperback, the book has a sewn binding that will give years of service and can be rebound again if the pages ever work loose.

For a little over a month, I have tested *The Night Sky* side by side with four of the popular field guides, and I find that for constellation sweeping it beats them all. When I head out into the yard for star gazing, I grab it, the binoculars or the Astroscan, the red flashlight, and I'm set

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for observing. In the daytime, the book sits on the shelf above the computer, ready for instant reference.

Looking for faults, I found two. First, the guide won't satisfy rabid deep-sky enthusiasts with their giant Dobsonians since it doesn't show enough objects. Second, rank beginners might find it hard to use since they won't know when a given constellation is visible.

For deep-sky nuts — go away, this guide wasn't written with you in mind. And for you beginners, I recommend learning the main constellations before purchasing this book. By the time you are using binoculars or a small scope, you'll find this wonderful little star guide the perfect companion for observing runs. *Robert Burnham.*

Patrick Moore's Armchair Astronomy

Patrick Moore
185 pages, cloth, $16.95
W.W. Norton & Company (1984)

Patrick Moore has become such a venerated institution in backyard astronomy that his name sells more books than his titles. No doubt this is why his publishers decided some time ago that Moore's name should be a part of his book's titles.

His unassailable reputation is maintained with *Patrick Moore's Armchair Astronomy*, an interesting hodgepodge of vignettes about astronomy and astronomers from both historical and modern perspectives. There are also a number of personal entries that give the book a travelogue-like tone, which adds greatly to its readability.

In the foreword, Moore describes the book as "a series of 'snippets' with no particular theme, but ranging over the whole astronomical scene." It is a book, Moore says, that the cloud-bound astronomer can open at random and pass the time with until the sky clears.

There are a number of wide-ranging topics, from profiles of little-known astronomers, to telescopes, to colliding galaxies and pulsars. Each entry is brief — on the average, a page or page and a half — and the book is generously illustrated. Some sections are written tongue-in-cheek and others are in a graceful but prosaic style.

The fun thing about this book is that you can open it to practically any page and read something interesting. For instance, entry 47, titled, "How Wrong We Were," is a cogent statement about how misled the scientific community was about Mars prior to the first successful probes. Not only do you gain insight concerning how confident science can be about a subject and still be way off the mark, but you also learn something about Mars — at least what astronomers believe is true today.

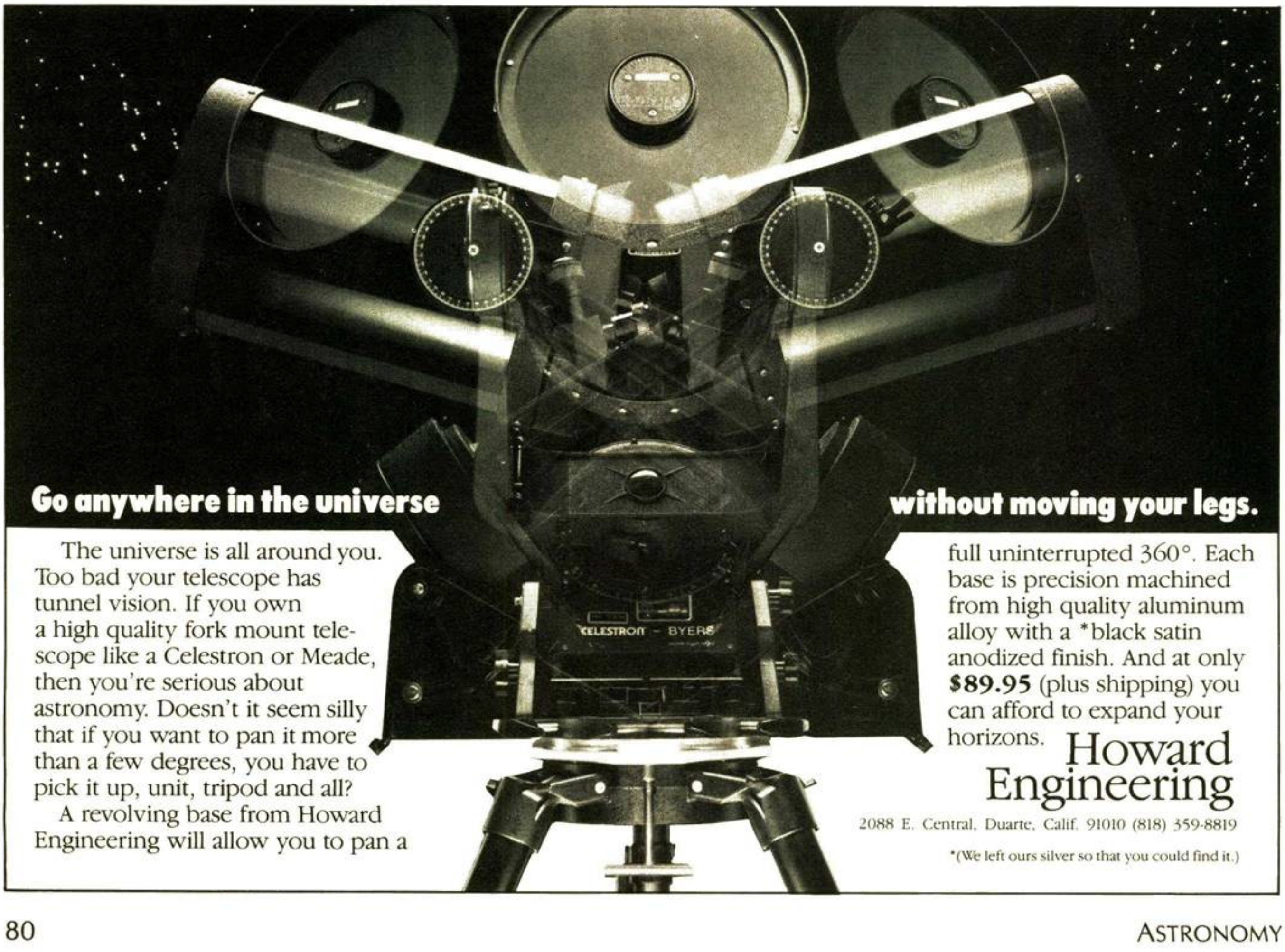
There are other intriguing entries: an early astronomer's views concerning life on a comet, the mystery surrounding whether Sirius was once red-hued, and the history of the great Arizona meteor crater from the moment the first white men (presumably representatives of modern civilization) discovered it in 1871.

This is an interesting and entertaining book that backyard astronomers will no doubt enjoy perusing on cloudy nights or any time they feel like exploring astronomy. *Jeff Kanipe.*

Radio Stars

Robert M. Hjellming and
David M. Gibson, eds.
411 pages, hardcover, no price given
D. Reidel (1985)

This book contains the proceedings from a workshop on stellar continuum radio astronomy held in 1984 at Boulder, Colorado. Subjects covered include the physics of stellar radio emission, observational and theoretical aspects of stellar winds and bipolar flows, radio-emitting pre-main sequence stars, active binary stars, dwarf flare stars, radio emission from x-ray binaries, and the techniques and problems involved in stellar radio astronomy.



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Commission Report Foresees A Bold Future in Space

The National Commission on Space has seen the future of the United States space program, and it is ambitious. The commission's report, "Pioneering the Space Frontier," is the result of a year-long investigation into the future goals and opportunities of the space program over the next fifty years.

The 214-page report proposes an agenda for the nation to follow into the next century. Specific programs are described in the space sciences, the exploration and settling of the solar system, and the commercial use of space. Also outlined are the means to these ends: the technological advances, policy decisions, and funding required.

The report proposes a "vigorous space science program" in the following areas:

- global study of the Earth's surface and atmosphere with satellites and the Space Station;
- the influence of space on human biology and other life forms;
- solar and space physics, including studies of plasma and the Sun's effect on the Earth and human activity in space;
- solar system studies, specifically sample-return missions to Mars, comets, and asteroids, and;
- astronomy and astrophysics, using new observatories in low-Earth orbit and on the far side of the Moon.

According to the report, the advancement of scientific understanding inevitably leads to human exploration and settlement. "Exploration, settlement, and enterprise are closely connected actions. We have explored both to search for scientific truth and to find valuable resources. In exploring and settling the inner Solar System, we expect the same close connections to prevail."

The report recommends a program of settlement starting with "prospecting" probes to the Moon and establishment of permanent lunar bases. This would be followed by missions to resource-rich asteroids and to Mars and its moons.

This spectacular celestial light display, the result of an experimental chemical release, could be seen from the eastern United States during the pre-dawn hours of May 13. Two canisters of barium and one of strontium were released at an altitude of over 400 kilometers by a pair of sounding rockets launched from NASA's Wallops Flight Facility on the Virginia coast. The strontium release, shown here, glowed deep blue with a beam of sunlight-induced ions flowing up the lines of Earth's magnetic field. The experiment was designed to investigate the critical velocity effect theory of Nobel Prize winner Hannes Alfven. This theory has been used to explain the systematic distribution of the planets and their satellites as well as other details in the early formation of the solar system. Although analysis of the experimental data is not complete, preliminary results indicate the effect took place. NASA/Wallops Flight Facility photo.

To enable the United States to achieve these goals, the report recommends extensive research and development programs in several areas. Advances in propulsion technology, spacecraft design, robotics, and processing of extraterrestrial materials are proposed. The report also recommends that NASA's space research and technology budget, now only 2 percent of the agency's total budget, be increased to 6 percent.

To conduct this intensive research effort, the report recommends the establishment of a new entity, the National Space Laboratory, to administer the various space research facilities and allocate laboratory time among applicants. Research funding, the report suggests, would come not only from NASA but from other agencies, such as the National Science Foundation, as well as industry and academia.

The report also depicts international cooperation and the involvement of the private sector as crucial to the success of its proposed goals. Financial resources would be provided by an expanding American economy, which the report envisions as growing at an annual rate of 2.4 percent. At this level of growth, the recommended space program could be funded at its current percentage level of the gross national product.

The report recommends that NASA emphasize long-range planning by adopting a twenty-year civilian space program and five-year budget plans. This

A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.

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long-range perspective, the report points out, could also result in cost savings produced by multi-year rather than annual expenditures.

The Commission's recommendations now await review by the President, the Senate Committee on Commerce, Science, and Transportation, and the House Committee on Science and Technology.

Spots in Atmosphere May Be Caused by Mini-Comets

Since its launch in 1981, NASA's Dynamic Explorer (DE-1) satellite has revealed mysterious dark spots in global images made of Earth's ultraviolet dayglow — sunlight absorbed then re-radiated by high-altitude oxygen atoms. At first it was thought that these spots were errors in the imaging process. However, as the spots continued to appear in subsequent images, they were interpreted by at least one group of scientists as being a true phenomenon.

Louis Frank, John Sigwarth, and John Craven of the University of Iowa have proposed that the dark spots are caused by the vaporization of comet-like clumps of "dirty ice" that shed gases in the upper atmosphere.

In a paper published in the April 1986 issue of *Geophysical Research Letters,* Frank and his colleagues state that approximately 30,000 spots have been identified in the DE-1 images made during a total observing period of about 2,000 hours from late 1981 to early 1985. According to the scientists, these previously "undetected comet-like objects" are composed primarily of fluffy water-snow enclosed in a dusty mantle. An increase in the number of spots was noted on January 3, 1982, during the Quadrantid meteor shower.

By far the most serious problem with this theory is the amount of water vapor that the mini-comets are said to be adding to the atmosphere. Frank and his team calculate that the mass of each comet is about 100 tons. This value, coupled with the estimated occurrence rate of twenty comets per minute (for both hemispheres), implies a staggering amount of mass influx for the Earth's atmosphere, on the order of one billion metric tons per year. The additional cometary mass would equal the atmospheric mass every 5 million years if the mini-comet influx rate was maintained over that period.

This has prompted several researchers to express reservations concerning this theory. Thomas Donahue of the University of Michigan in Ann Arbor questions the incredible rate that these comets are supposed to be coming into the Earth's atmosphere.

"The rate at which these comets are bringing water into the atmosphere," said Donahue in a telephone interview, "is over three orders of magnitude higher than the rate at which hydrogen is escaping from the Earth." This amounts to about 1,000 times less water than that being brought in by mini-comets, he added.

Donahue also points out that the influx of comets should not be exclusively an Earth phenomenon. Their effects should also be detected on other planets. Venus' atmosphere, for example, would double its water content in 5,500 years. On Mars, the proposed cometary influx would have supplied an ocean's worth of water during the past few hundred million years.

If these spots are not caused by comets, then what are they? Donahue says that he knows of one theory that suggests these spots are caused by heavy cosmic ray ions. Or, he speculates, they might be concentrations of molecular oxygen transported there by upper atmospheric cyclones.

"There are many other possible explanations worth exploring that don't involve comets," said Donahue.

Comet Trails Detected By IRAS

Analysis of photographs taken by the Infrared Astronomical Satellite (IRAS) has revealed faint, narrow dust trails that are apparently associated with the orbits of known periodic comets.

In a paper published in the May 30, 1986, issue of *Science*, authors Mark Sykes, Larry Lebofsky, Donald Hunten, and Frank Low of the University of Arizona, contend that these trails — sometimes seen both ahead of and behind the orbital position of the comets — consist of debris ejected from comet nuclei during perihelion passages, when comets lose the most mass.

As a comet approaches the Sun, debris is dislodged from the nucleus by active jets or the solar wind and strewn along the comet's wake. This material, which can be comprised of both large and small particles, then assumes an orbit that is nearly identical to that of the parent comet. The average age of these dust trails is hundreds of years. Consequently, they consist of the debris deposited over numerous comet passages.

The brightest trail was that associated with Comet Tempel 2. Stretching some 75 million kilometers in length, the trail also extended both ahead of and behind the comet. The trail's apparent width was about 4 arcminutes, corresponding to a true width of 260,000 kilometers. No debris was observed dispersing into the orbital plane, nor was there any deviation of the trail from the projected orbit of the comet.

A dust trail associated with Comet Gunn was much fainter, although the material behind the comet was significantly brighter than the material ahead. The scientists suggest that this cometary jetsam is due to the emission of smaller particles that are easily carried back along the comet's orbit by the solar wind.

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Deviating from the characteristics of other dust trails was the one associated with Comet Encke. For example, the trail exhibited a greater apparent width than the other trails by nearly a factor of two. Because Comet Encke comes closer to the Sun at perihelion than any other comet (0.34 AU) — and therefore must experience more violent nucleus activity — its wider dust trail may be caused by material ejecting at higher velocities and consequently reaching greater distances from the nucleus.

But according to the science team, it is also possible that Comet Encke may be a different type of comet from Temple 2 and Gunn, having a nucleus that differs in composition, density, and particle size. The scientists speculate that analysis of such dust trails may provide a means of classifying fundamental differences between comets.

Balloons Probe Venusian Atmosphere

On June 11 and 15, 1985, two balloons carrying meteorological instruments were released by the Soviet spacecraft Vega 1 and Vega 2 into the middle cloud layer surrounding Venus, about 54 kilometers above the planet's surface. Scientists tracked the probes for 46 hours as they moved over 11,000 kilometers of the Venusian atmosphere, until the probes' batteries failed.

The probes provided the first extended *in situ* measurements of Venusian atmospheric properties, including air pressure, temperature, and horizontal and vertical wind velocities. These data were telemetered to Earth while the balloon's motion was tracked by very long baseline interferometry using twenty ground tracking stations around the world.

The initial results, published in the March 21, 1986, issue of *Science*, buttress data gathered by previous Venus probes concerning the planet's hellish atmosphere. The temperature at the "float level" of the balloons was measured at 320 K (116.6° F), a mild environment compared to temperatures in the lower atmosphere, which reach 600 K (620° F) 20 kilometers above the surface, and 750 K (891° F) at the surface. Horizontal wind velocity at the 54-kilometer level was clocked at 248 kilometers an hour.

One surprise was the velocity of the vertical winds. Downward-flowing wind gusts at times reached 12 kilometers per hour, considerably stronger than scientists had predicted. Vega 2 was caught in a series of strong downdrafts lasting over an eight-hour period. One of these carried the balloon to the 50-kilometer level where it floated over the highest parts of Aphrodite Terra, a mountainous region. Scientists speculate that winds blowing over this area caused atmospheric or "lee" waves that rise to balloon level.

Another revelation was a 6.5 K difference in temperature readings between the two balloon probes, which was larger than predicted. Apparently the balloons were floating within air masses of different temperatures, even though both probes straddled the equator (but at different longitudes). This suggests that there are Venusian air masses with separate and distinct "thermal histories" from that of the main air mass, and that, as eddies do on Earth, might carry heat from the equator toward the poles.

Scientists anticipate that detailed analysis will render additional information on Venusian meteorology and perhaps lend insight into the workings of Earth's atmosphere.

Chesley Bonestell Dies at 98

Chesley Bonestell, the "dean of astronomical artists," died June 11, 1986, at his home in Carmel, California. Born January 1, 1888, in San Francisco, Bonestell was trained as an architect. He worked on the Chrysler Building in New York City and the Golden Gate Bridge in San Francisco. Later he became a masterful painter, and in 1949 collaborated with Wernher von Braun and Willey Ley on a book of astronomical paintings called *The Conquest of Space*. This work was followed by *Beyond the Solar System* and *The Exploration of Mars*, all graphic depictions of a future few people then believed would come.

Bonestell also produced matte paintings for many motion pictures, including *Citizen Kane, The Hunchback of Notre Dame, When Worlds Collide*, and *War of the Worlds*.

The numerous Bonestell paintings reproduced in his books and in magazines, such as *Collier's, Life, Look*, and *Scientific American*, inspired a generation of astronomical artists.

Naval Observatory Info Line

On August 3 the U.S. Naval Observatory in Washington, D.C., opened a public service telephone line for basic astronomical information. Called Starwatch, the 900 number features a recorded message containing information about planetary positions, meteor showers, eclipses, and other special events in skywatching.

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October 2-5
Okie-Tex Star Party (sponsored by the Oklahoma City Astronomy Club), Lake Murray, Oklahoma. Contact: Joe Pearson, 700 Teal Pl., Edmond, OK 73034.

October 4
Telescope Users' Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

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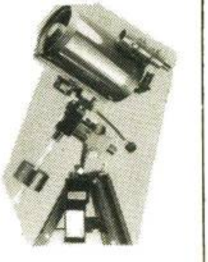

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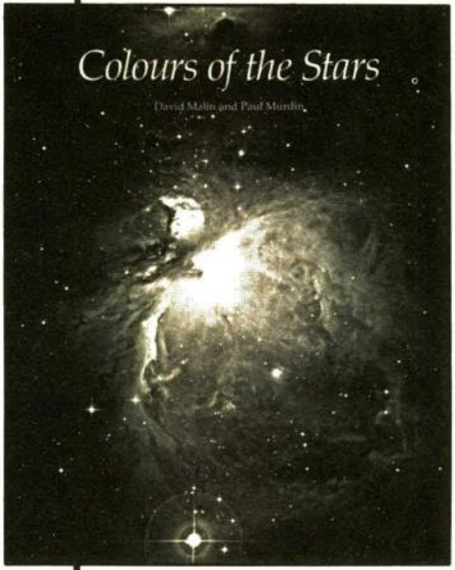

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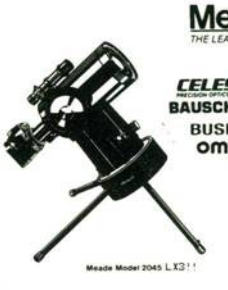

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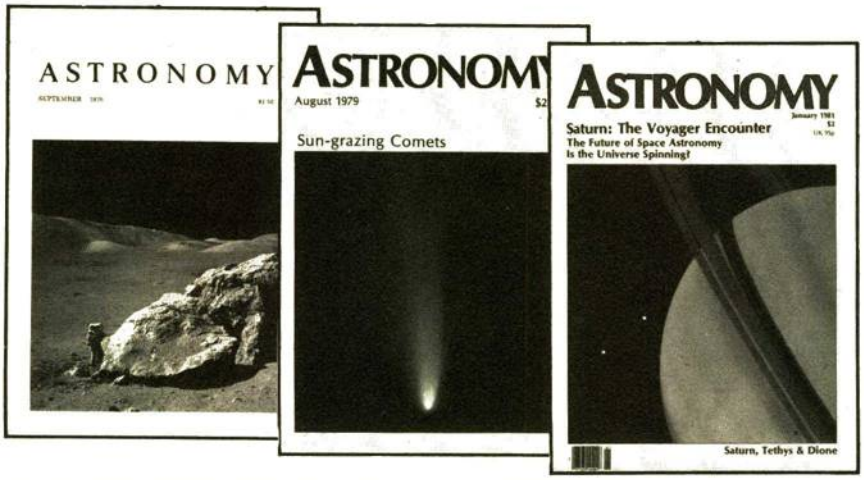
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Goodbye, Halley!

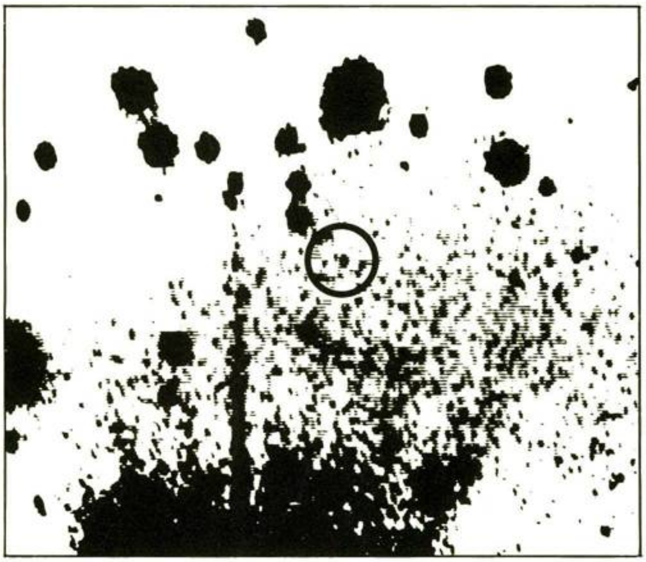
by David J. Eicher

An old familiar friend slips behind the Sun, but not without leaving a lifetime's worth of memorable images.

On September 17 Halley's Comet reaches solar conjunction. It sets with the Sun and is consequently invisible from our vantage point in the solar system. The famous visitor will return in October's morning sky, but by then it will appear as a tiny, 13th-magnitude fuzzball even in the largest amateur telescopes. Halley's real show ended last June when it faded below naked-eye visibility.

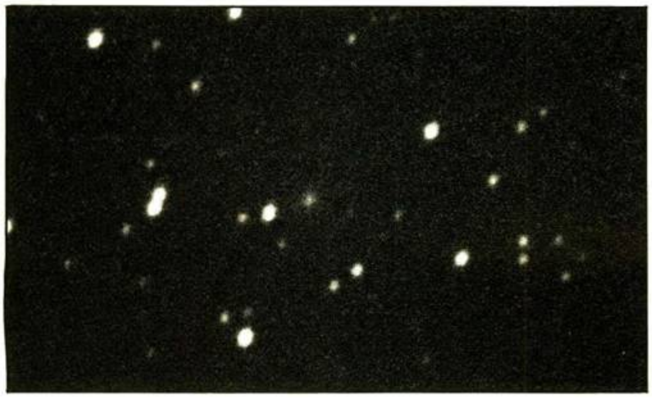
Although the comet was more than twice as distant from Earth as it was in 1910, and the apparition was widely touted as "the worst in 2,000 years," the show given by Halley had many high points. There were ample opportunities for professional astronomers to scrutinize Halley with giant telescopes equipped with photometers, spectroscopes, astrometric instruments, and low-light CCD cameras. There were five spacecraft encounters — two Soviet, two Japanese, and one European — that produced data that will be analyzed for years and will doubtlessly provide astronomers with their best model of a comet to date.

And perhaps most importantly for backyard stargazers, there were plenty of opportunities to see a comet that, even though it didn't look as impressive as Comet West in 1976, still won a special place in the hearts of amateur astronomers.



Above: This first image of Comet Halley in its current apparition was made by Caltech astronomer G. Edward Danielson and then-graduate student David Jewitt with the 5-meter Hale telescope and a CCD camera on Palomar Mountain, California. When the image was made on October 16, 1982, Halley lay outside the orbit of Saturn and barely glimmered at magnitude 24.2. Caltech photo.

Below: Backyard astronomers equipped with 17.5-inch and 20-inch telescopes first saw Halley in August 1985 when the comet had brightened to 15th magnitude. This photo was made on August 18 with a 16-inch f/5.5 reflector. Photo by Bill Hall.



1982: The Race for Recovery

October 16, 1982. A cold, calm night on Palomar Mountain, California, some 35 miles northeast of San Diego. Two young astronomers, G. Edward Danielson of the California Institute of Technology, and David Jewitt, a graduate student at Caltech, have the 5-meter Hale telescope for the night. They also have a sensitive charge-coupled camera on loan from the Space Telescope program.

The two astronomers are in a race to be the first to recover Comet Halley, a race that's been going on for the past five years at observatories worldwide — though nobody really wants to admit it. They are acutely aware that Halley's Comet, which hasn't been observed for nearly seventy years, may well be within the reach of the 5-meter telescope and their CCD camera — but just barely. After all, the comet is one billion miles from both the Sun and Earth.

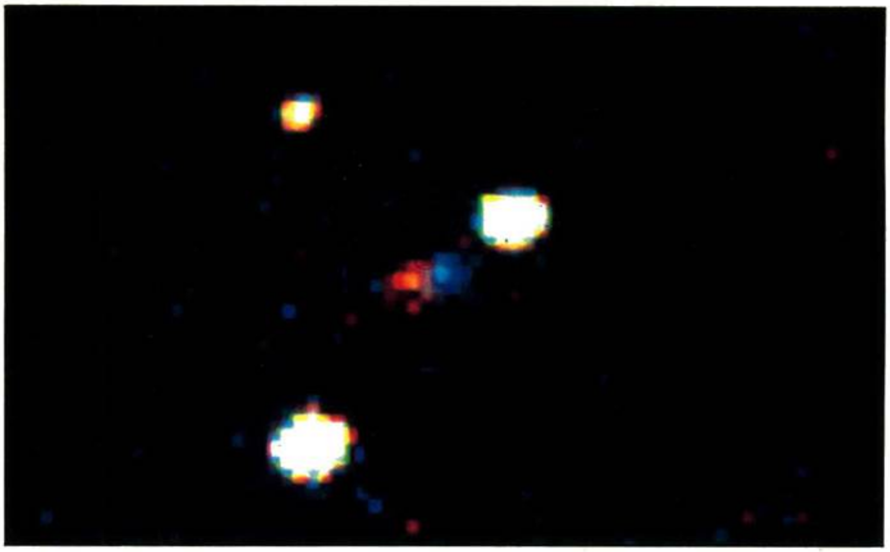
Interrupting their normal routine of imaging galaxies and quasars, Jewitt and Danielson move the giant telescope to look toward the exact spot where Halley should be in Canis Minor. They take five 8-minute exposures of the area despite an annoyingly bright 8th-magnitude star just outside the field. Analyzing the frames, they find that indeed a magnitude 24.2 object is in exactly the right spot. Subsequent exposures show the comet's motion.

Having communicated the recovery to Brian Marsden of the Central Bureau for Astronomical Telegrams, the two astronomers and their colleagues prepare the data they've collected and report it for inclusion in Circular 3737 of the International Astronomical Union, issued on October 21, 1982. The recovery announcement reads:

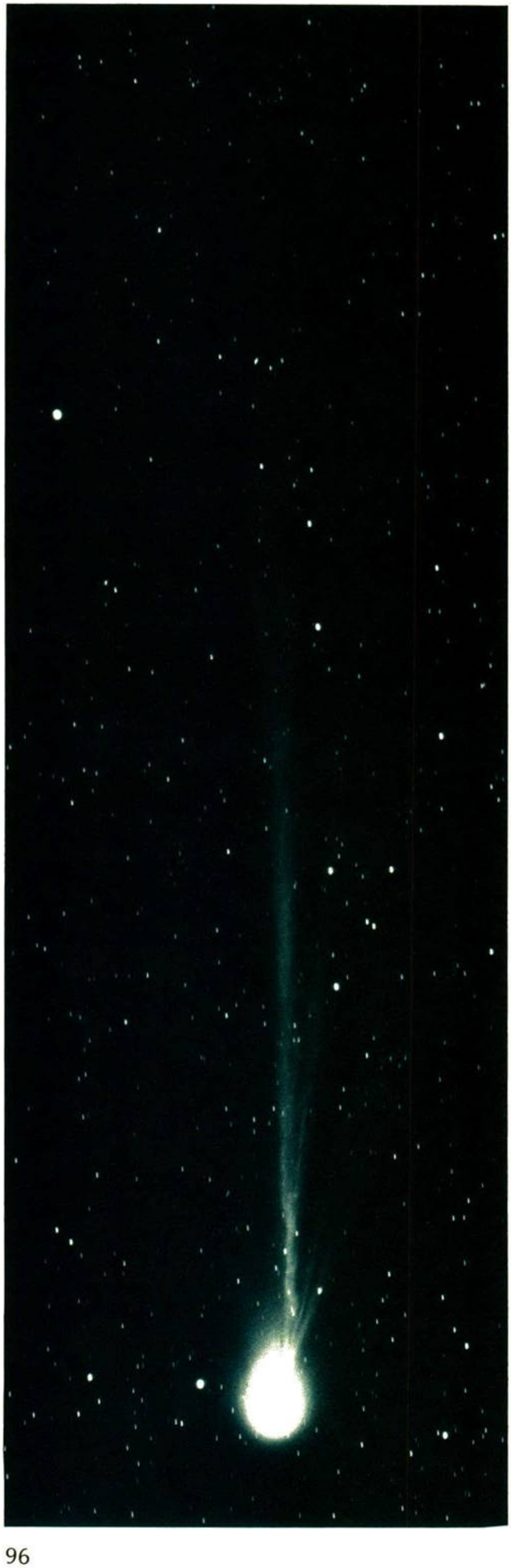
"PERIODIC COMET HALLEY (1982i). D.C. Jewitt, G.E: Danielson, J.E. Gunn, J.A. Westphal, D.P. Schneider, A. Dressler, M. Schmidt and B.A. Zimmerman report that this comet has been recovered using the Space Telescope Wide-Field Planetary Camera Investigation Definition Team charge-coupled device placed at the prime focus of the 5.1-m telescope at Palomar Observatory. Five exposures of 480-s effective duration each (in seeing measured to be 1.0″ fwhm) were taken on Oct. 16 through a broad-band filter centered at 500 nm. Definite images near the expected position and having the expected motion of P/Halley were noted. No coma was detected, and the object had a Thuan-Gunn magnitude of [g] = 24.3 ± 0.2 (corresponding to V $\sim$ 24.2; and presumably B $\sim$ 25)."

Halley was recovered — it hadn't secretly dissipated before returning — but it was exceedingly faint. On New Year's Day 1983, as the excitement from the recovery began to die down, a realization set in for anxious would-be Halley observers. Granted, professional astronomers would now study Halley's behavior in a variety of ways, but it would be a long, slow period of anticipation — some two and a half years — before the comet would brighten to visibility in backyard telescopes.

***Right:** Sensitive CCD cameras showed that by February 16, 1985, Halley's image was distinctly different from those of the surrounding stars, but it was still a 17th-magnitude speck of light. Photo by Rudolph Schild, courtesy Smithsonian Astrophysical Observatory.*



***Below:** Early in November 1985 Halley had brightened to naked-eye visibility. By November 15, the 6th magnitude comet passed within 4° of the Pleiades star cluster in Taurus. The two formed an irresistable target for hundreds of astrophotographers. Photo by Mace Hooley, using an 8-inch f/1.5 Schmidt camera.*



1983-1985: The Wait

Backyard astronomers are generally an impatient group. They want to observe special events — eclipses, supernovae, occultations, bright comets — as soon as possible, and they rarely can get enough of them. It's now early 1983, and the recovery has injected new life into the media coverage of Halley's Comet. But there is nothing to look at; all the talk is simply that — talk. Further aggravated by a growing number of Halley-related products and increased prices for astronomical equipment, the Halley experience in 1983 and 1984 takes on a carnival-like atmosphere.

It is the biggest buildup of publicity the astronomy world has experienced in many years, and clearly the market is attempting to make the most of it. Commemorative T-shirts, buttons, posters, coffee mugs, key chains, medallions, postage stamps — you name it and it's offered for sale, emblazoned with some sort of Halley logo. This commercialization of Halley sours and frustrates many backyard observers who want simply to get on with the show and see what the famous comet will really look like.

Observationally, a few amateur astronomers claim to have spotted Halley with small instruments when it was still extremely faint. The period following Halley's recovery and the first observations by amateurs is the worst during the apparition.

1985: Halley Arrives

Mid-August 1985. Halley has moved out of conjunction with the Sun and brightened to about 15th magnitude. This enables those backyard observers with Halley maps and telescopes in the 16-inch to 24-inch range to spot Halley under a very dark sky. And they do: reports of observations begin pouring into ASTRONOMY's offices by the dozens.

On September 1, 1985, Halley lies in the constellation Orion between the bright stars 68 and 71 Orionis. It appears as a 14th-magnitude "star," identifiable only because of its slightly fuzzy image. This causes disappointment since Halley was expected to be a magnitude or more brighter by this time. It lies at a distance of 254 million miles from the Sun and 277 million miles from Earth — only about one-fourth the distance of Jewitt and Danielson's recovery observation. A photoelectric measurement made on September 13, 1985, by Robert Millis of Lowell Observatory, reveals that Halley's V magnitude is 13.8.

Because of the orbital geometry involved, October 1985 sees Halley's motion against the sky speed up as the comet moves into Taurus. This will be the month when great numbers of backyard observers get their first view of the comet as it brightens to magnitude 11 early in the month and continues at a dramatic rate, reaching 8th magnitude by month's end. On October 27 Halley performs its first celestial trick, passing through the gap separating the bright star Zeta (ζ) Tauri and the Crab Nebula. Although it happens when the Moon interferes badly, many astrophotographers seize the opportunity to record all three

Left: Having developed a short tail during December 1985, Halley became a respectable comet early in the New Year. This photo, made on January 10, shows a 4th-magnitude coma and a 3.5°-long gas tail, a combination that made for an impressive view in small telescopes and binoculars. Photo by Henry L. Giclas using the 13-inch "Pluto camera" at Anderson Mesa, Arizona. Lowell Observatory photo.

Opposite page: Comets are generally most active after perihelion and Halley was no exception. During March 1986 the comet's coma brightened to magnitude 2.5 and its ion tail lengthened to 10° as the comet passed through Sagittarius. During the early morning hours of March, thousands of spectators witnessed Halley's Comet using small telescopes, which showed a bright coma and kinks in the tail, and in binoculars, which showed a subtle streak of gray light. This detailed photo of Halley on March 30, made with Cerro Tololo's Curtis Schmidt camera, shows the comet near its peak. Photo by Arturo Gomez, courtesy Cerro Tololo Interamerican Observatory.

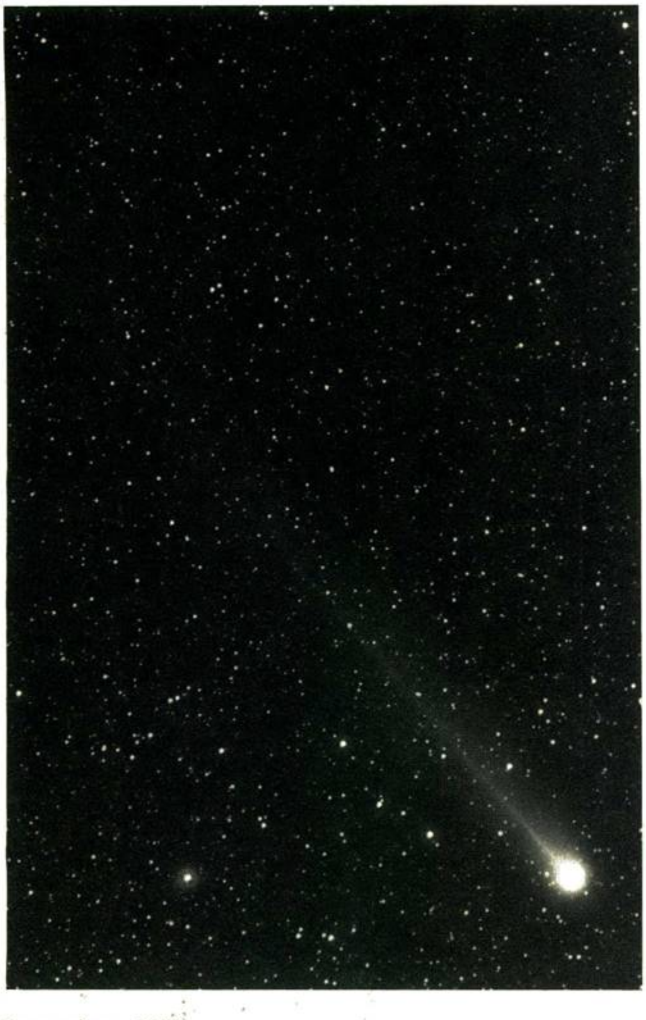
objects together in a single frame.

Overcoming its early dimness, Halley's magnitude reaches 6.5 and its coma grows to 30′ by the first week in November. On November 9 Stephen Edberg and Charles Morris of NASA's Jet Propulsion Laboratory, both experienced comet observers, make the first naked-eye sighting of Halley since 1910 from a 7,000′-high mountaintop in southern California. A week later, as the comet passes within 4° of the Pleiades cluster, many observers see Halley as a small fuzzy spot with the naked eye. Astrophotographers by the score record the scene for posterity. By the end of November Halley's Comet is brighter than 6th magnitude and shows an asymmetry in its coma that suggests a tail will sprout at any time.

During December the comet moves away from the rich Taurus Milky Way and passes through relatively barren starfields in Pisces and Aquarius. At mid-month Halley reduces its distances to 118 million miles from Sol and 76 million miles from Earth, and it grows a gas tail some 2° long. But its coma magnitude, according to Morris' visual observations, seems to have stabilized at about 5th magnitude. The best show before perihelion will be in January of the New Year in the evening sky just after sunset.

Opposite page: By mid-April 1986 Comet Halley was slightly brighter than 3rd magnitude, but its tail had virtually disappeared. Early in the month, Halley had drastically slowed down in its production of gas and dust. To visual observers all that remained of the comet was a short, broad dust fan emanating from the coma. On April 15 the comet lay just 2° away from the giant elliptical galaxy NGC-5128 in Centaurus. Five degrees south of the pair lay the biggest and brightest globular cluster in the sky, Omega Centauri. Photo by Barney Magrath, using a 300mm f/4 telephoto lens.

Below: In mid-May Halley dimmed but was still an impressive sight under a dark sky, with a 4th-magnitude coma and a tail stretching 7° long. A month later Halley dropped to 7th magnitude and its followers dwindled to only diehard comet observers. Photo of Halley on May 11 by Bob Yen.



1986: Halley Gives Its All

During the first days of 1986 University of Texas astronomer Gerard de Vaucouleurs reports visual magnitudes for Halley of 5.2 (January 1st), 5.1 (3rd), 5.0 (5th), and 4.9 (6th). Under a dark sky, observers report seeing distinct gas and dust tails, the gas tail measuring as much as 5° long. Halley is getting better, providing its first grand show. By late January, however, Halley moves close enough to the Sun that it becomes invisible. On February 9 the comet reaches perihelion at a distance of 55 million miles from the Sun.

Early in the morning of February 15 astronomer Richard West and his colleagues at the European Southern Observatory in La Silla, Chile, are the first to see Halley after its perihelion passage. They describe Halley as quite bright, about 3rd magnitude, and showing a few degrees' worth of tail even in the brightly lit predawn sky. This gives observers around the world hope that the show will be impressive in March and especially in April, when Halley approaches Earth and should brighten dramatically.

Although no one knows it at the time, March turns out to be the best time to observe Halley. By the 15th the comet is displaying an 8°-long tail in binoculars and its coma, according to Morris, shines at visual magnitude 2.5. Rising out of the horizon haze a couple of hours before sunrise, the comet lies among the stars of Sagittarius, just below the Teapot asterism, and is an obvious naked-eye smear of light under a dark sky. It isn't a Comet West or Bennett or Ikeya-Seki, but it is a respectable and enjoyable comet to view. On the 15th Halley passes within 2° of the globular cluster M-75, and on the 24th the comet moves within 4° of the much larger globular M-55. Astrophotographers take advantage of both events, producing dozens of shots showing two objects on a single negative.

On the night of March 20/21 the comet undergoes a major "disconnection event." A long section of the comet's gas tail breaks away. Lots of disconnection events have occurred before, but this time the tail didn't re-form. Only during the last days of March did the comet's tail again span more than 5°.

Then came the unexpected. During the first few days of April, as the comet crosses into Scorpius and sinks much lower in the sky for Northern Hemisphere viewers, it simply stops producing gas and dust — Halley loses all but a couple of degrees of its tail. All that remains is a wide, bow-shaped delta of dust perhaps 2° long, emanating from a bright coma of about magnitude 2. The coma is bright, but without a bright tail component Halley's Comet appears far less impressive in April than it had in March.

The comet passes near numerous deep-sky objects in April, the most notable being the lenticular galaxy NGC-5128 on the 15th, and nearby Omega (ω) Centauri. At the end of the month Halley re-forms a long, very faint tail. During the lunar eclipse on April 24, many observers report seeing a thin tail stretching 25° across the sky, while the coma magnitude is 3.5, according to Morris.

During early May, just when Halley was expected to rapidly fade, the comet actually undergoes a bit of a renaissance. On the 4th Halley, positioned just north of the bright star, Nu (ν) Hydrae, glows at 4th magnitude and shows a bright, rather wide tail some 7° long. Observers who look for the comet in May expecting to see a faded remnant are delightfully surprised. In another three weeks, however, Halley's Comet fades to 7th magnitude and its tail shrinks to a negligible degree or so.

Many observers see Halley's comet in early June 1986, but the excitement caused by its visit has abruptly vanished. The comet is now a circular patch of light with a bright center but little detail. Sitting outside under the stars in June, all that one can think of is that the long awaited show is finally over.

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Photography
in
Astronomy

Processing Astroslides Yourself

by
Mace Hooley

Now that you've shot some great astrophotos, how do you get your film processed? You could take it to a photo lab and wait several days to get the results, but the anticipation of possibly having made the shot of a lifetime would kill you. What's worse is hoping that the lab technicians can recognize a nebula from a fogged exposure and don't clip off (or through) your best shots.

But why wait and worry when you can do it yourself, not only saving money but time and possibly your exposures as well? Besides, astrophotos need to be developed as soon as possible before the latent (exposed) image fades. And who knows better than you just how the final images should look?

Where in your house should you do this? Surprisingly, the best place is probably your kitchen sink; and you don't even need a darkroom.

The easiest films to process yourself are those that render a projector-ready image right out of the developing soup, namely the fast color slide films like 3M 1000 and Fuji P1600D (professional film), or even the slower Ektachromes exposed through fast telescopes or camera lenses.

With developing kits now available at photo supply stores, processing slide films is easier than ever before. Unicolor's Rapid E-6 kit, for example, contains just three chemicals: the developer, color developer, and the blix (a mixture of bleach and fix). The total processing time is under thirty minutes.

Just what do these chemicals do? The first developer changes the latent image in the emulsion from exposed silver salts, which are colorless, into the metallic silver image with colored dyes, thus creating a visible image. The color developer combines the colored dyes with color-dye couplers to make a positive color image. Finally the blix removes the metallic silver and simultaneously "fixes" and clears the film to allow light to pass through the finished transparency.

You'll need very little equipment to process slide film, and virtually everything can be purchased at a local photo supply store. Start with a one- or two-reel developing tank. I recommend using the stainless steel kind with the plastic top and metal reels (total cost: $15) because they dry quickly and cause the least chemical carry-over from step to step. Plastic reels, however, are generally easier to load but they require an oversized tank.

You'll also need an absolutely dark place to load the film onto the reel. A dark closet at midnight may do, but a more viable alternative is to purchase a photographer's changing bag. This is a light-tight bag with sleeves that you slip your arms through. The bag allows you the freedom to load or unload film even in a brightly lit room. At a cost of about $10, it's well worth the money, especially if it keeps you out of a stuffy closet.

As for developing agents, either Kodak's Hobby-Pac E-6 or Unicolor's Rapid E-6 chemicals, available in quart bottles, will work well. For $13 you can process about twelve rolls of film. You'll also need four one-pint bottles to put your mixed "soup" in as well as one sixteen-ounce graduate to accurately measure your chemicals in.

In addition, you'll need slide mounts. The Pakon plastic mounts run about seven cents each and work very well. And by all means purchase a good dial-type thermometer, which is faster reacting and easier to read than the mercury type. However, be careful not to bang the housing as this could cause it to give a false reading. An excellent model by Weston runs about $12. Finally, a watch or automatic timer will be needed to time the respective development phases.

Once you have the essentials you're ready to begin processing. The first thing to do is mix the chemicals. Just follow the directions that come packed with the chemical kit, taking care not to splash the developer since air bubbles will oxidize the chemicals, causing your developer solution to lose its effectiveness. Mix enough to fill your developing tank completely; this will help process the film more evenly.

Now we come to the trickiest part of the home development process: loading your film onto the reel for placement inside the developing tank. Since you must do this in the dark using only your sense of touch, you might as well prepare yourself to go slowly and carefully. In fact, you might want to experiment with a throwaway roll of film first. If possible, ask someone at the photo store to show you how it's done. Remember, too, that you're working with a very delicate material. You don't want to scratch the emulsion when it's out of its cartridge or kink the film when spooling it onto the reel.

Place everything you need into your changing bag (or closet). This will include film, reel (use both reels if it's a two-reel tank), tank, and tank top, plus a pair of scissors and an ordinary can opener to open the film cartridge. If you're using a changing bag, zip it up completely; if you're working in a closet, give your eyes a few minutes to dark adapt so as to be sure that no light is leaking in.

When you're ready, open the film cartridge with the can opener, pull the spool with film out of the metal canister and cut the end of the film off square. Leave the plastic spool attached to the film.

Insert the film into the reel so that its natural curl tends to curve around the reel's core. This makes it much easier to load. For plastic reels, insert the film a few inches into the side of the reel. Then, with the film hanging, grasp the top and bottom of the reel and rotate it back and forth. This will pull the remaining film onto the reel. Once the film is nearly all wound on, cut off the dangling spindle and wind the last few inches on.

Metal reels are somewhat more difficult to load. With the film curving toward the core, insert the end of the film into the core where the very end slips under a

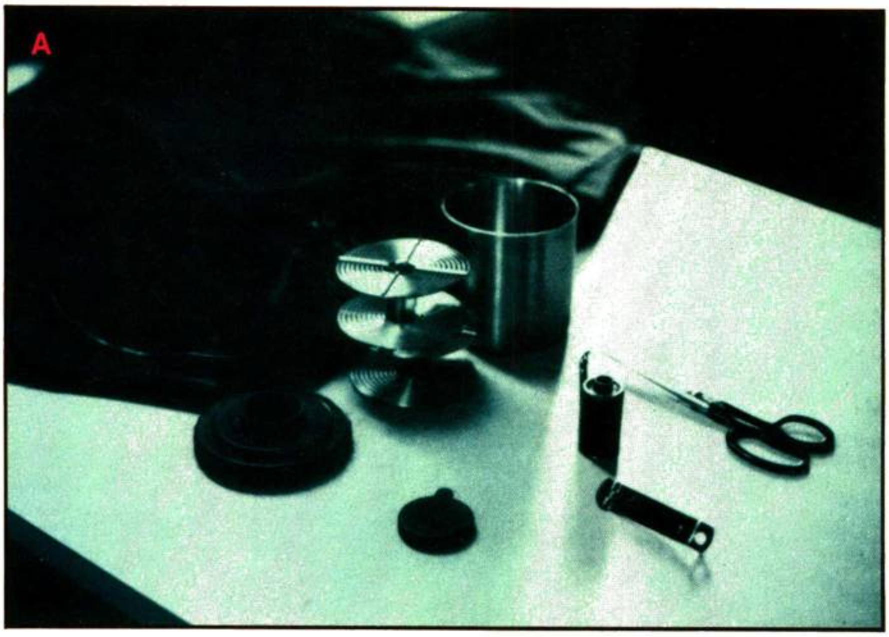
This shot of the Lagoon Nebula was made using 3M 1000 slide film, a 10-inch f/4.5 reflector, and a 23-minute exposure. Photo by Pierre Schwarr.

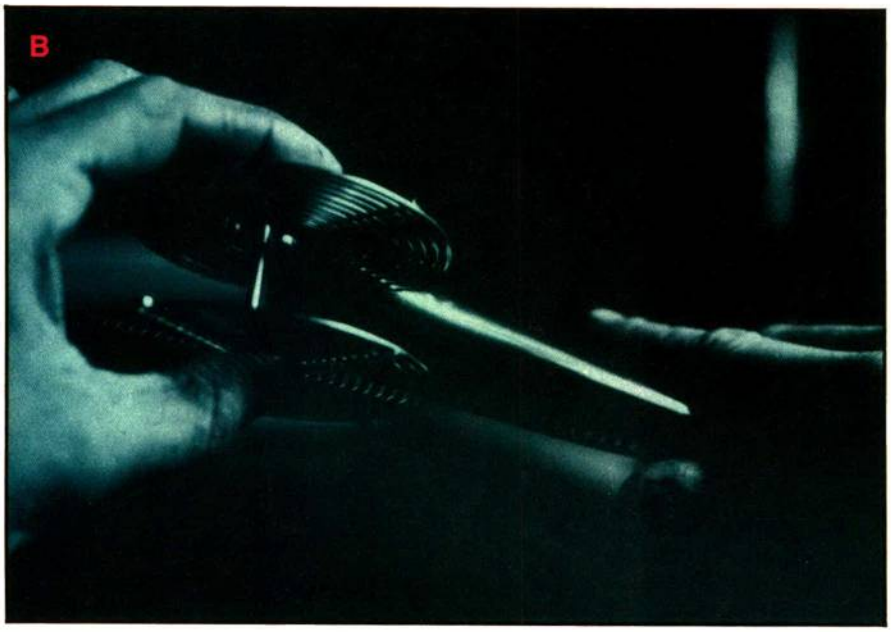
spring clip. Hold the film by the edges with just enough pressure to bow the film slightly. Doing so will allow it to fit between the wire of the reel so it can be wound on easily. Then as before, clip off the spool when almost all of the film is wound on, then wind on the rest.

Once the film is loaded, the rest is easy. Place the reel inside the tank, attach the lid securely, and set it aside in the bag or closet.

Temperature control of the chemicals is very important when developing color films, both for getting consistent results and the optimum color balance. The easiest way to maintain the necessary 100° F temperature is to use a "water jacket" — your kitchen sink filled with warm water. Place all of your bottles in the sink and fill it with water that is 102° F. Why 102° and not, as dictated by the E-6 process, 100°, plus or minus half a degree? Because as the film is developing, the tank temperature will drop about 4°, and it's the average temperature that's most important. This temperature control technique is known as the "drift-by" method. The tank temperature drifts by the desired temperature halfway through each step. Maintain the 102° jacket temperature by adding small amounts of hot tap water.

Once all of the chemicals have reached 102°, you're ready to process. Make sure your first developer is at 102°, your tank with cap (or stirring rod on certain types of tanks) is ready, and your timer, clock, or watch is handy. What you do for each step is pour a chemical into the tank, "agitate" — that is, move it over the film to insure even development — then pour it out.





(A) The essentials for loading your undeveloped film into a developing tank include photographer's changing bag (or dark closet), a film tank (a two-reel steel tank is pictured here with its lid and cap off and stacked reels sitting outside tank), scissors, and a can opener.

(B) Although metal reels can be difficult to load, the job is easier if you bow the edges of the film slightly so that it fits between the edges of the reel. This photo shows how the film should look as you begin to load it (but remember that this is always done in the changing bag or closet!).

(C) The water jacket is simply a kitchen sink filled with 102° tap water to warm and maintain the temperature of the processing chemicals. In this photo, the temperature of the developer is being monitored prior to use. Note the timer on the edge of the sink, which will be used to time each developing stage.

(D) Once the second stage of the chemical process (the color developer) has been completed, the film is no longer light sensitive and the lid may be removed for adding the blix and rinsing with 90° to 100° tap water.

(E) After the film has been processed and rinsed, squeegee the water from the surface of the film by running it between your fingers; blot dry with a soft paper towel to prevent water spotting.

A few quick notes about agitation. It's very important to agitate thoroughly, but not too much. Excessive agitation can damage the film. With sealed metal and plastic tanks a single "agitation" is one inversion of the tank and righting it. For plastic tanks not designed to be inverted a rod is inserted through the tank and into the reel; one complete rotation followed by another in the opposite direction is equal to one agitation. For each chemical in most color processes, you agitate twice every fifteen seconds for the duration of time given in the packaged instructions for each development stage — no more and no less.

Pour in the first developer and agitate twice, note the time, rap the tank hard on the counter or sink to dislodge any air bubbles that may be clinging to the film, then let it sit for fifteen seconds. Agitate twice every fifteen seconds until the first developer time is up.

If you choose to "push process" your film — that is, process it for two, three, or even four times its rated speed — just extend the first developing time. Add two minutes for a one-stop push, four minutes for a two-stop push, and seven minutes for a three-stop push.

Fifteen seconds before the first developing time is up, pour the developer out and, with the top still on the tank but the cap off, fill and drain the tank six times with warm (90° to 100°) water. This washes away any developer still on the film and makes it ready for the color developer.

Repeat this same procedure for the color developer and then the blix (except that times are not changed for push processing). Once the color developer is done, the film is no longer light sensitive, so it's okay to pull the top off the tank for the second rinse, blix, and remaining steps.

After the blix is complete, wash the film thoroughly (according to the directions supplied with the chemicals), pull the film from the reel, and hang it up to dry. It's a good idea to run the film strip between your fingers to remove excess water and then blot it dry with a soft, folded paper towel. This will help it dry faster and practically eliminates water spots.

Hang the film in a place away from foot traffic and dust and allow it to dry for two to four hours. The film is then easily cut into frames and mounted, ready for the slide projector.

One of the big advantages of processing your own slides is the pleasure of doing it all yourself, from taking the photo to developing the final image. There's nothing quite like seeing a murky, barely-there image of M-31 or M-8 come out of the color developer, then watching the blix transform it into a bright, striking image just hours after the exposure.

Mace Hooley is an astrophotographer living in Phoenix, Arizona. His recent articles include "Fundamentals of Astrophotography," which appeared in the May 1986 issue, and "Astrophotography with Tech Pan 2415 Film" in the July 1986 issue.

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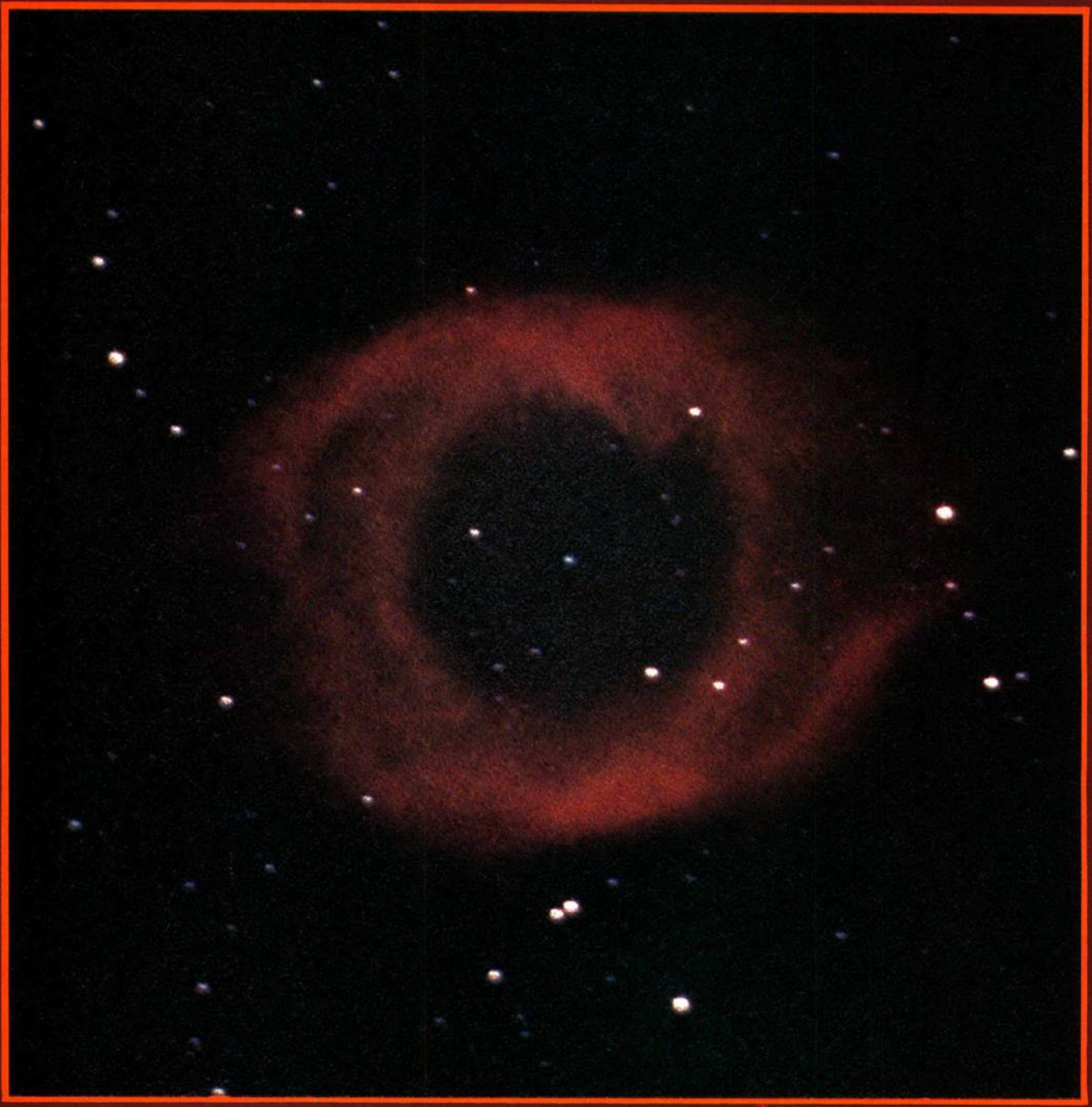


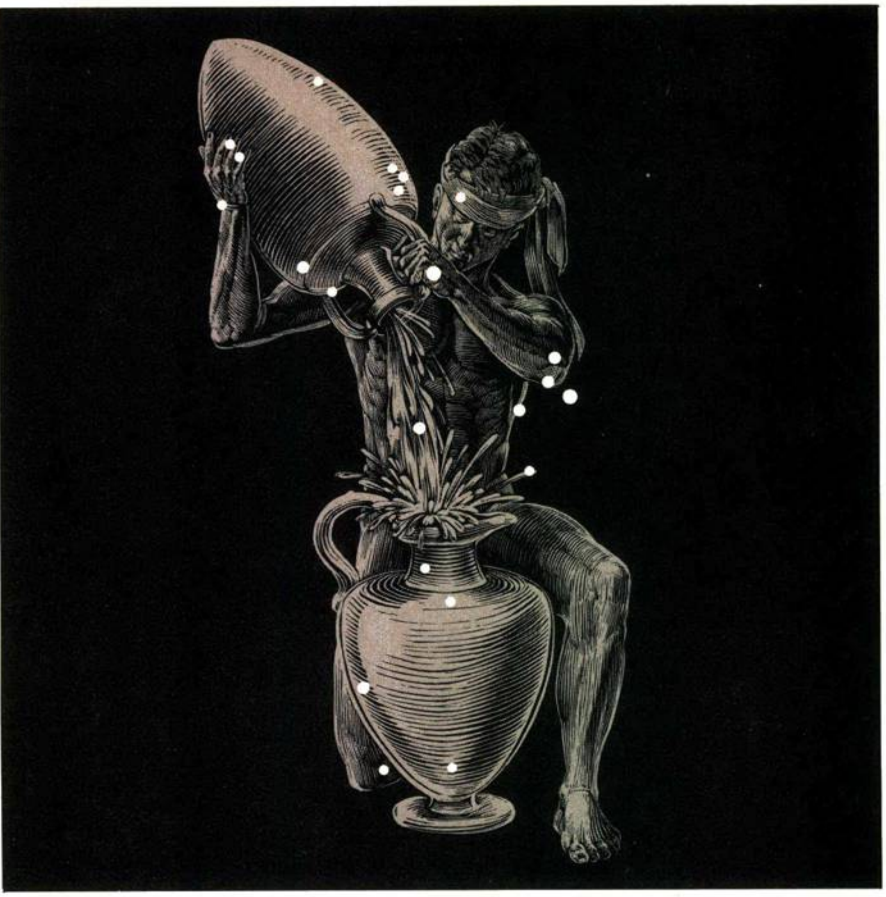
Above: The Helical Nebula is the largest and brightest planetary nebula in the sky, but its low surface brightness makes it difficult to see on nights of poor transparency. Photo by Jack B. Marling.

Far left: M-2 is a magnitude 6.5 globular cluster whose edges resolve into stars in a 6-inch telescope. Photo by Kim Zussman.

Left: The Saturn Nebula, NGC-7009, is known for its faint ''ears'' extending on either side of the nebula. These nebular extensions photograph easily but are very difficult to observe. Photo by David Healy.

Aquarius

Aqr
Aquarii


Keith Ward

Lying between the Great Square of Pegasus and the barren starfields of Capricornus and Piscis Austrinus, **Aquarius** the Water Bearer is sufficiently far away from the plane of the Milky Way that it contains relatively few galactic objects. The only notable members of the galaxy in the constellation are two bright planetary nebulae and several unusual stars and clusters. Aquarius is loaded, however, with faint galaxies, a few of which are impressive when viewed with backyard telescopes.

The most atypical deep-sky object in Aquarius is the sprawling **Helical Nebula** (NGC-7293). Also nicknamed the Helix, NGC-7293 is the largest and brightest planetary nebula in the sky, measuring some 769″ (nearly 13′) across and shining at photographic magnitude 6.5. The Helical Nebula is large and bright because it is relatively close, only about 150 parsecs away. (This is an average distance based on many widely discrepant figures.)

You might assume that the Helix, so named because its ring shape resembles a helical coil, would be an easy target even under slightly imperfect skies. This isn't the case, however. Its light is so spread out that individual parts of it appear dim and have a low contrast against the sky background.

To best observe the Helical Nebula, choose a night and time when the Moon is absent from the sky, the transparency is very good, and Aquarius is near its highest nightly elevation. Acquaint yourself with Aquarius and find the south-central part of the constellation; you'll see two 5th-magnitude stars catalogued as Upsilon (υ) and 57 Aquarii. The Helix lies between these stars, about a third of the way from Upsilon toward 57 Aqr.

When searching for the Helix use a low-power, wide-field eyepiece. A good nebular filter may help if your observing site is light polluted. If you have a 6-inch or larger scope you may see the nebula as a roundish patch of greenish gray light some 10′ across without any distinct features. If you can see it without difficulty, increase the magnification to something like 15x per inch of telescope aperture. A 10-incher at 150x shows the dark "hole" inside the nebula and subtle brightness variations along its edges, as well as several faint stars involved in the nebulosity. One of these stars, a 13th-magnitude bluish star at the dark hole's center, is the central star and is visible in 8-inch and larger scopes.

Another Aquarian planetary lies far to the north and is much smaller. With a photographic magnitude of 8.3 and a diameter of only 25″, the **Saturn Nebula** (NGC-7009) — so nicknamed because of ansae (projecting arms of nebulosity extending out on either side of the disk) — is small enough that its surface brightness is very high. It is relatively easy to find and observe with virtually any telescope.

The Saturn Nebula lies in the western end of Aquarius, about 2° west of the 4th-magnitude star Nu (ν) Aquarii. Sweep for this object using a magnification of about 10x per inch of aperture; the nebula's small angular size makes it inconspicuous at very low powers. When you find the Saturn Nebula you'll see a bright, bluish green oval of light surrounding a 12th-magnitude bluish central star. On a night of exceptional seeing, a good 10- or 12-inch telescope may show the ansae as faint projections of nebulosity spanning 44″ and ending in a bright condensation. If you see these delicate features, you'll be in a relatively select group of backyard observers who have seen such detail in a planetary nebula.

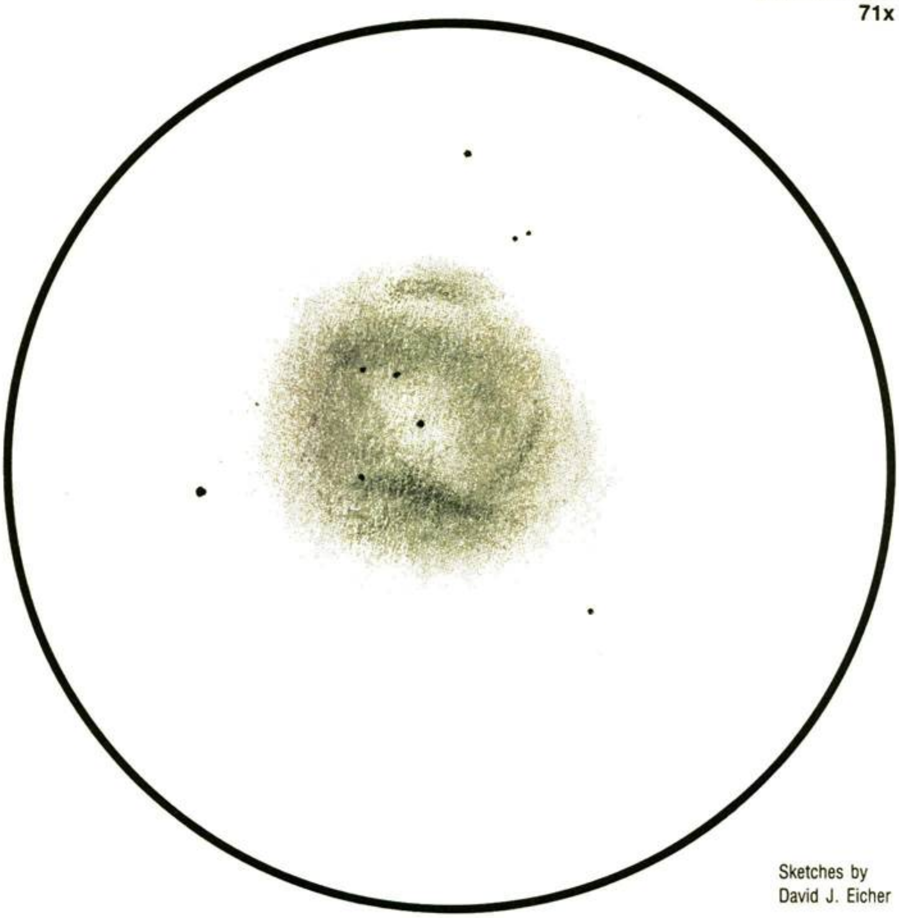
Some 2° southwest of the Saturn Nebula is a curious group of four stars that appear as a fuzzy smear of light in small finder scopes. This little asterism is Messier object **M-73** (NGC-6994). Charles Messier described it as "three or four small stars which look like a nebula at first sight; it contains a little nebulosity." Measuring 2.8′ across and glowing at photographic magnitude 8.9, it appeared to Messier to contain nebulosity when he observed the group in October 1780. Modern photographs show no nebulosity in the area, suggesting that Messier was simply mistaken. In fact the group is probably not a cluster but a chance alignment of stars lying at different distances. Although unspectacular in the eyepiece, M-73 is a curiosity of deep-sky cataloguing worth viewing at least once.

Only 1.5° west and slightly north of M-73 is the fine globular cluster **M-72** (NGC-6981). Shining at magnitude 9.4 and measuring nearly 6′ across, finder scopes show this object as a fuzzy, enlarged "star"; small telescopes at low power reveal a 4′-diameter disk without any resolution. But a 6- or 8-inch scope

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

NGC-7293

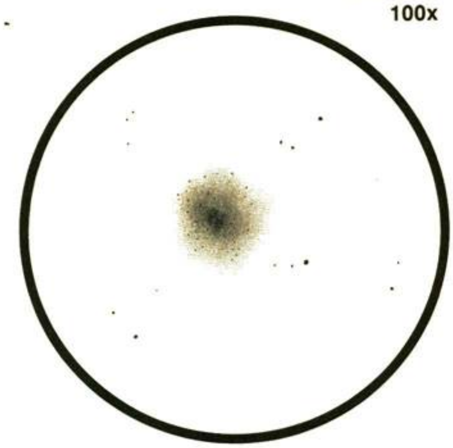
17.5-inch
f/4.5 reflector
71x



Sketches by
David J. Eicher

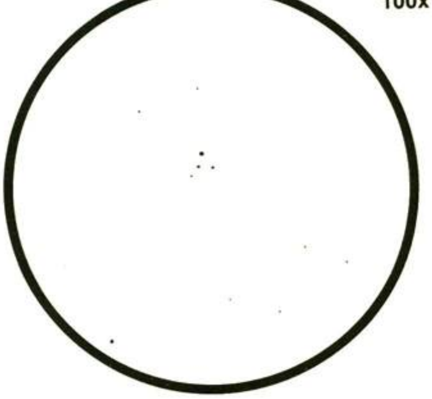
M-2

8-inch
f/10 SCT
100x



M-73

8-inch
f/10 SCT
100x



at high power in steady seeing will resolve stars along M-72's edges. Telescopes of 16-inches or more aperture show M-72 looking rather like M-13 as seen with a small scope.

Far more impressive is **M-2** (NGC-7089), a globular located 5° north of the bright double star Beta (β) Aquarii. This cluster is twice as large as M-72 and far brighter (magnitude 6.5), offering a satisfying view even in small scopes at low powers. M-2 is an obvious nonstellar blob of light in finder scopes and appears as an 8′-diameter disk in a 6-inch reflector at high power. On a dark night a 17.5-inch scope at 71x nicely resolves the cluster into myriad stars.

A third globular in Aquarius is **NGC-7492**, a large (6.2′ diameter) cluster composed of faint stars summing up to an integrated magnitude of 11.5. NGC-7492 lies 3.5° due east of the bright star Delta (δ) Aquarii and appears as a 4′-diameter pale gray disk in small scopes. Resolution of this cluster is difficult since the brightest giants in the cluster are quite faint. The largest backyard telescopes may resolve a few stars along the edges of this faint cluster on the very best of nights.

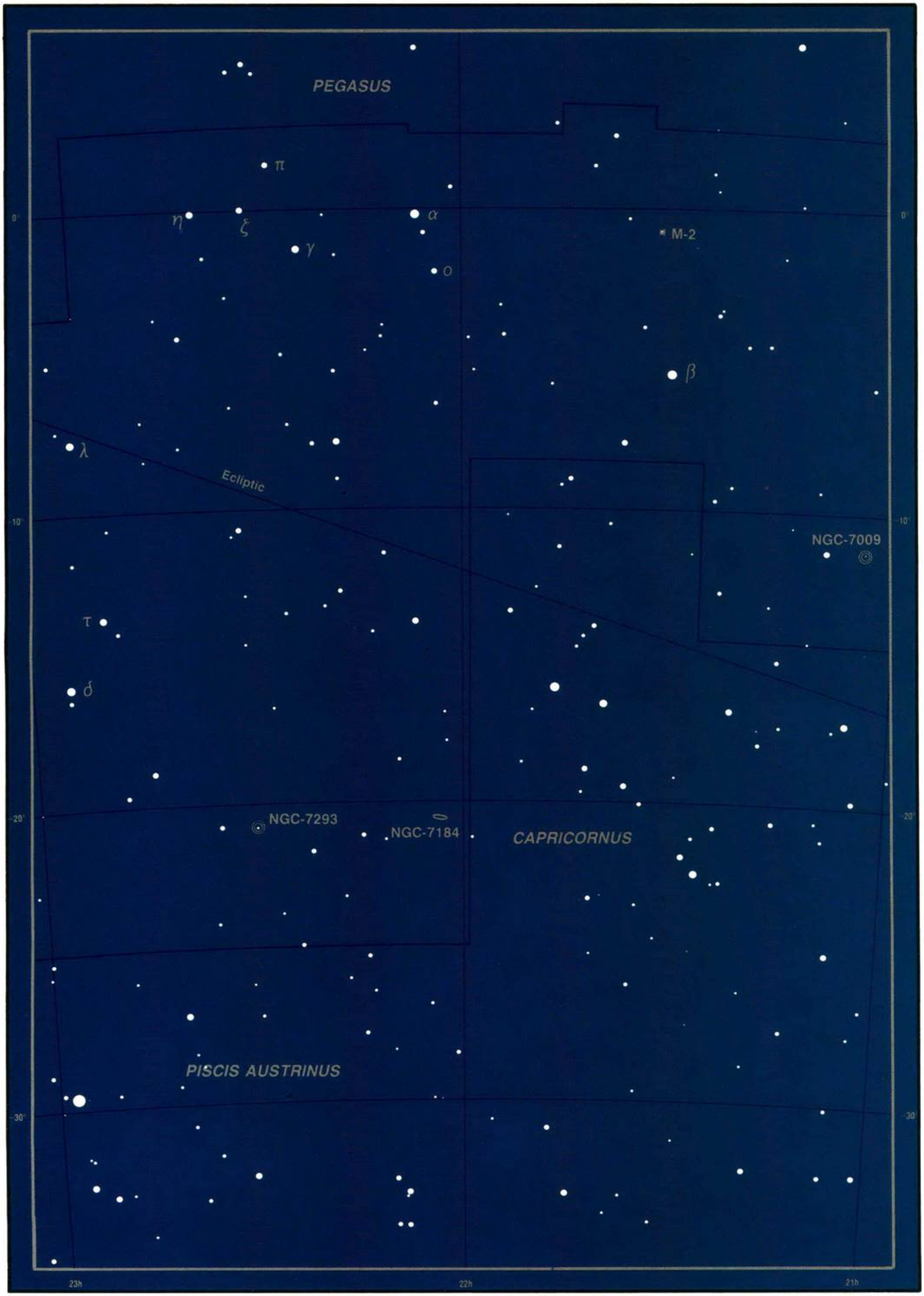
Aquarius contains a slew of galaxies but only a few of them are bright enough to show detail in backyard scopes. Lying a degree apart in the northeastern part of the constellation are **NGC-7723** and **NGC-7727**, two 11th-magnitude spirals. NGC-7723 is an Sb-type spiral measuring 3.6′ by 2.6′ across, and NGC-7727 is a barred spiral spanning 4.2′ by 3.4′. **NGC-7606** is another 11th-magnitude spiral; its spiral arms measure 5.8′ by 2.6′, and it contains a bright nucleus. **NGC-7184** is a large Sb-type spiral glowing at blue magnitude 12; with dimensions of 5.8′ by 1.8′ it appears as a silvery needle of light in small telescopes.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-6981	M-72	●	20h 53.5m	−12°32′	9.4	5.9′	
NGC-6994	M-73	∷	20h 59.0m	−12°38′	8.9_P	2.8′	
NGC-7009		■	21h 04.2m	−11°22′	8.3_P	25″	
NGC-7089	M-2	●	21h 33.5m	− 0°49′	6.5	12.9′	
NGC-7184		§	22h 02.7m	−20°49′	12.0_B	5.8′x1.8′	Sb⁺
Zeta (ζ)		★²	22h 28.8m	− 0°07′	4.3, 4.5	1.5″	
NGC-7293		■	22h 29.6m	−20°49′	6.5_P	769″	
NGC-7492		●	23h 08.4m	−15°37′	11.5	6.2′	
NGC-7606		§	23h 19.1m	− 8°29′	10.8	5.8′ x 2.6′	Sb⁺
NGC-7723		§	23h 38.9m	−12°58′	11.1	3.6′ x 2.6′	Sb
NGC-7727		§	23h 39.9m	−12°18′	10.7	4.2′ x 3.4′	S(B)a pec
R		LPV	23h 43.8m	−15°17′	5.8↔12.4	387d	

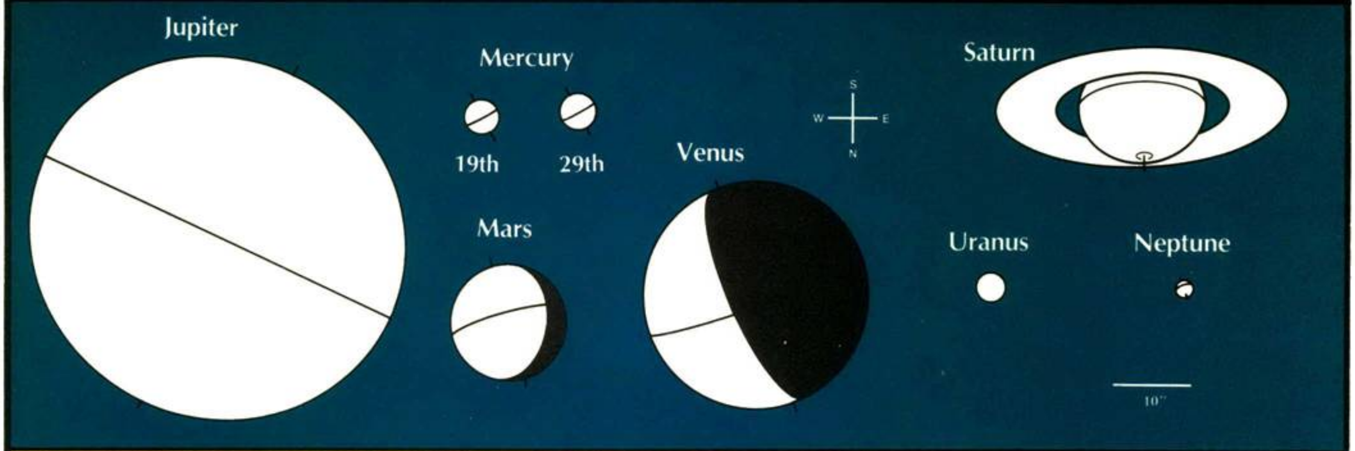
H = Hubble type for galaxies

Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.

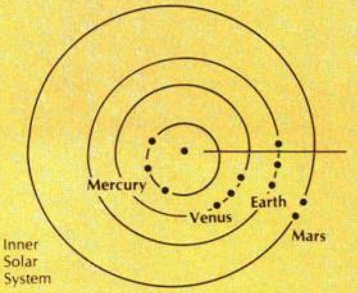
★²	*Double Star*
LPV	*Long Period Variable*
∷	*Asterism*
●	*Globular Star Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*

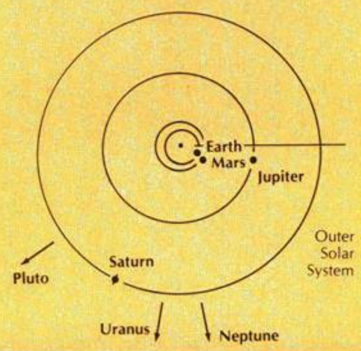

PEGASUS
π
0°
η
ξ
α
γ
ο
M-2
0°
β
λ
Ecliptic
-10°
-10°
NGC-7009
τ
δ
-20°
NGC-7293
NGC-7184
CAPRICORNUS
-20°
PISCIS AUSTRINUS
-30°
-30°
23h
22h
21h

Planetary Data September 1986


Jupiter
Mercury
19th
29th
Mars
Venus
S
W
E
N
Saturn
Uranus
Neptune
10''

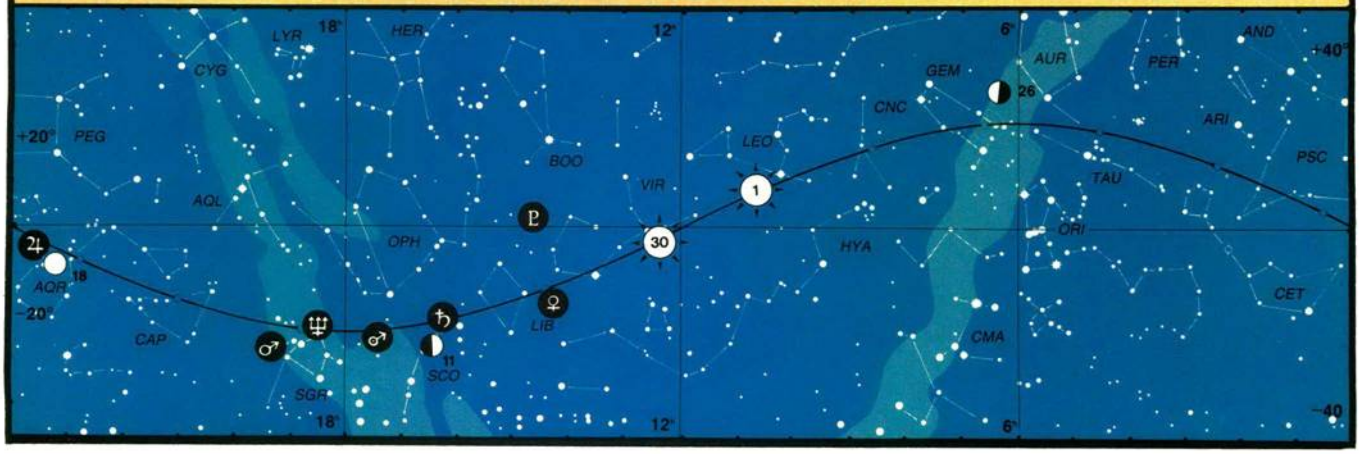
	Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun	1	−26.7	31.8′	—	1.01	—	—	158°16.7′	10h 40.4m	8°24.1′
	15	−26.7	31.9′	—	1.01	—	—	171°52.3′	11h 30.8m	3°09.2′
	30	−26.7	32.0′	—	1.00	—	—	186°32.7′	12h 24.7m	−2°40.2′
Mercury	1	−1.6	5.1″	98%	1.33	0.34	139°43.7′	153°51.6′	10h 25.6m	11°45.2′
	15	−1.0	4.9″	97%	1.39	0.42	199°26.0′	179°57.7′	12h 01.6m	0°55.7′
	30	−0.3	5.2″	88%	1.31	0.46	244°48.1′	204°15.2′	13h 28.9m	−10°04.9′
Venus	1	−4.4	25.9″	46%	0.65	0.73	298°44.3′	203°23.3′	13h 26.5m	−11°51.1′
	15	−4.5	31.1″	38%	0.54	0.73	320°52.8′	216°21.4′	14h 10.8m	−17°35.5′
	30	−4.6	39.1″	26%	0.43	0.73	344°38.9′	226°01.6′	14h 48.1m	−22°14.6′
Mars	10	−1.4	16.3″	89%	0.57	1.38	325°58.1′	287°00.0′	19h 15.8m	−26°46.7′
	20	−1.2	14.9″	87%	0.63	1.38	332°18.7′	290°53.2′	19h 32.7m	−25°46.0′
Jupiter	15	−2.9	49.5″	100%	3.97	4.98	348°14.1′	347°30.2′	23h 16.4m	−6°20.0′
Saturn	15	0.6	16.1″	100%	10.26	10.00	249°45.8′	244°27.5′	16h 11.2m	−19°23.1′
Uranus	15	5.6	3.6″	100%	19.20	19.16	261°30.3′	258°47.5′	17h 10.8m	−23°03.7′
Neptune	15	7.9	2.2″	100%	30.03	30.24	274°54.7′	273°17.8′	18h 14.0m	−22°20.3′
Pluto	15	13.8	0.1″	100%	30.40	29.71	216°58.5′	215°48.3′	14h 34.9m	1°44.7′


Mercury
Venus
Earth
Mars
Inner Solar System


Earth
Mars
Jupiter
Saturn
Pluto
Uranus
Neptune
Outer Solar System

Moon Data

New Moon......September 4 at 7h10m
First Quarter......September 4 at 7h41m
Full Moon.......September 18 at 5h34m
Last Quarter......September 26 at 3h17m
New Moon........October 3 at 18h55m
First Quarter.......October 10 at 13h28m
Perigee: Sept. 12 at 0h05m...369,754 km.
Apogee: Sept. 25 at 10h02m...404,333 km.


LYR
18°
HER
12°
6°
AUR
AND
+40°
CYG
GEM
PER
CNC
26
+20°
PEG
ARI
LEO
BOO
PSC
TAU
AQL
VIR
1
ORI
OPH
30
HYA
18
AQR
−20°
LIB
CET
CAP
CMA
11
SCO
SGR
18°
12°
6°
−40

On April 12 Halley's Comet was low in the sky in the Northern Hemisphere but made a fascinating sight viewed from "down under." Ronald Royer's tricolor shot of Halley was made from Alice Springs, Australia, and shows the bow-shaped dust fan and the faint blue gas tail. By late May the comet had faded to 7th magnitude.

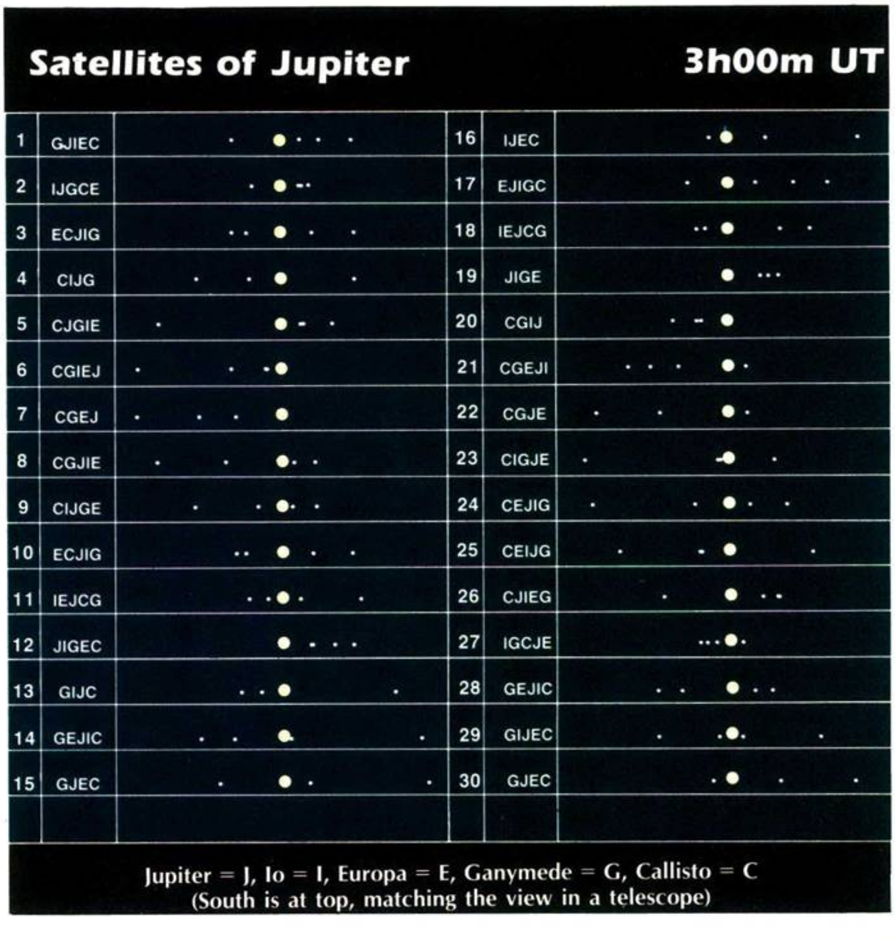
Mercury

On September 5, Mercury passes through superior conjunction and moves into the evening sky, but it won't become visible there until October, and then only poorly. The next good apparition will be the morning elongation in November and December that follows Mercury's transit of the Sun on November 13.

Venus

Although it is still brightening as it nears greatest brilliancy (−4.6 magnitude, on October 1), Venus has now sunk so low in the southwest that it is hard to observe with a telescope. Yet this is the period when its phase changes are the most interesting to watch. You'll do best to locate Venus in the sunset sky before it sets too low and the sky becomes completely dark.

If you observe each evening, you won't see much change from one day to the next. But after a week has passed, you'll notice that the crescent shape of Venus has grown distinctly larger and thinner. The best magnification to use will depend


Satellites of Jupiter
3h00m UT
1 GJIEC
2 IJGCE
3 ECJIG
4 CIJG
5 CJGIE
6 CGIEJ
7 CGEJ
8 CGJIE
9 CIJGE
10 ECJIG
11 IEJCG
12 JIGEC
13 GIJC
14 GEJIC
15 GJEC
16 IJEC
17 EJIGC
18 IEJCG
19 JIGE
20 CGIJ
21 CGEJI
22 CGJE
23 CIGJE
24 CEJIG
25 CEIJG
26 CJIEG
27 IGCJE
28 GEJIC
29 GIJEC
30 GJEC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

on the seeing conditions, but 100x will probably offer the best compromise between high power and turbulent images due to the planet's low elevation.

Earth

The center of the Sun crosses the celestial equator in a southward direction at 7h59m UT on the 23rd, thus marking the autumnal equinox and the beginning of fall in the Northern Hemisphere.

Mars

Mars is at perihelion on September 25, but the planet lies 98 million kilometers from Earth and presents a disk only 14.3″ across. This is about the last month that the planet's disk is large enough for you to see significant detail on it.

Use the highest magnification that atmospheric steadiness allows, even going as high as 50x per inch of aperture if the seeing is settled enough.

Minor Planets

1 Ceres (magnitude 8.4) lies in central Virgo, just west of 3rd-magnitude Zeta (ζ) Virginis. Its positions:

1st: 12h 53m 58s, 1° 15.6′
10th: 13h 10m 39s, −0° 28.7′
20th: 13h 26m 09s, −2° 22.5′
30th: 13h 41m 56s, −4° 13.7′

Ceres sets around 8:30 p.m. local daylight time on the 15th.

2 Pallas is in conjunction with the Sun on the 23rd and is out of sight all month.

3 Juno (11.2) is moving eastward in Ophiuchus, close to 3rd-magnitude Zeta (ζ) Ophiuchi. Its positions:

1st: 16h 19m 11s, −7° 51.6′
10th: 16h 25m 48s, −8° 39.6′
20th: 16h 33m 24s, −9° 31.8′
30th: 16h 42m 46s, −10° 21.8′

Juno sets about 11 p.m. local daylight time on the 15th.

4 Vesta (6.6) is moving retrograde in Cetus, about 10° north of 4th-magnitude Eta (η) Ceti. Its positions:

1st: 1h 18m 26s, −3° 31.1′
10th: 1h 14m 11s, −4° 30.3′
20th: 1h 07m 10s, −5° 40.5′
30th: 0h 58m 27s, −6° 47.9′

Vesta rises around 7 p.m. local daylight time on the 15th.

130 Elektra (11.4) is retrograding in southern Aquarius; it reaches opposition on September 8. Its positions:

1st: 23h 09m 56s, −16° 19.0′
10th: 23h 04m 28s, −18° 28.1′
20th: 22h 58m 26s, −20° 35.6′
30th: 22h 53m 28s, −22° 18.7′

Elektra sets around 5:30 a.m. local daylight time at mid-month.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

September 10 marks the date of Jupiter's opposition, the time when it is best observed since it is closest to Earth and visible all night long. Jupiter's equator spans 49.6″ — larger than any other planet ever gets (except Venus when it is close to inferior conjunction).

On March 9 Halley was near its best: the comet glowed at 3rd magnitude and sported a relatively bright 10°-long ion tail. Joe Hatfield's photo capturing the scene is this month's $100 "Best Astrophoto" winner. Hatfield used a piggybacked 105mm f/2.5 lens, 400 ISO film, and a 3-minute exposure.

Pick a clear evening and set your telescope outside at sundown so the optics can adjust to the temperature of the crisp, cooling air. (In a humid climate watch out for dew, however.) In about an hour, your scope will be ready to use, and by then Jupiter will be visible in the east.

Because Jupiter is still low, atmospheric seeing won't let the planet show off all its detail at once. Instead, make your first observations at low power. As Jupiter whirls on its axis once every 10 hours, don't be surprised if the disk looks subtly different after you've been viewing it for 30 minutes or so.

Around 1 a.m. Jupiter will be due south and at its highest elevation. Assuming the atmosphere is still steady, this is the time when you'll get your best high-power views.

Saturn

September is the time to make your last good observations of Saturn during this apparition. The planet will be visible throughout October, but will then have such a low elevation in the evening sky that telescopic viewing will be difficult.

Despite being over 10 astronomical units (1.5 billion kilometers) away, Saturn still spreads 16″ across — 36″ including the rings. Across its pale disk, pastel bands trace a washed-out version of Jupiter. To pull them into visibility try holding a light photographic filter, such as a Wratten 80A (light blue) or the Wratten 30 (magenta), over the eyepiece when you observe. The planet's equator and rings are tipped so as to place latitude +31° at the center of the Saturnian disk, which is roughly the region of greatest activity.

Uranus

Uranus lies in southern Ophiuchus and is an easy to find, 5.7-magnitude object that shows a 3.6″ disk under medium magnification. Start with magnitude-3.3 Theta (θ) Ophiuchi, shown on the Night Sky star dome on pages 58 and 59. Then, using your finder scope, sweep about 3° to the northwest. Uranus' bright greenish disk will be readily apparent.

Neptune

Finding Neptune calls first for aiming your finder scope at Lambda (λ) Sagittarii, the 3rd-magnitude star at the tip of the Teapot's "lid." Then slew the scope northwest about 7° to locate Mu (μ) Sgr. Neptune lies about 1½° south of Mu; it has an 8th-magnitude gray disk 2.2″ across.

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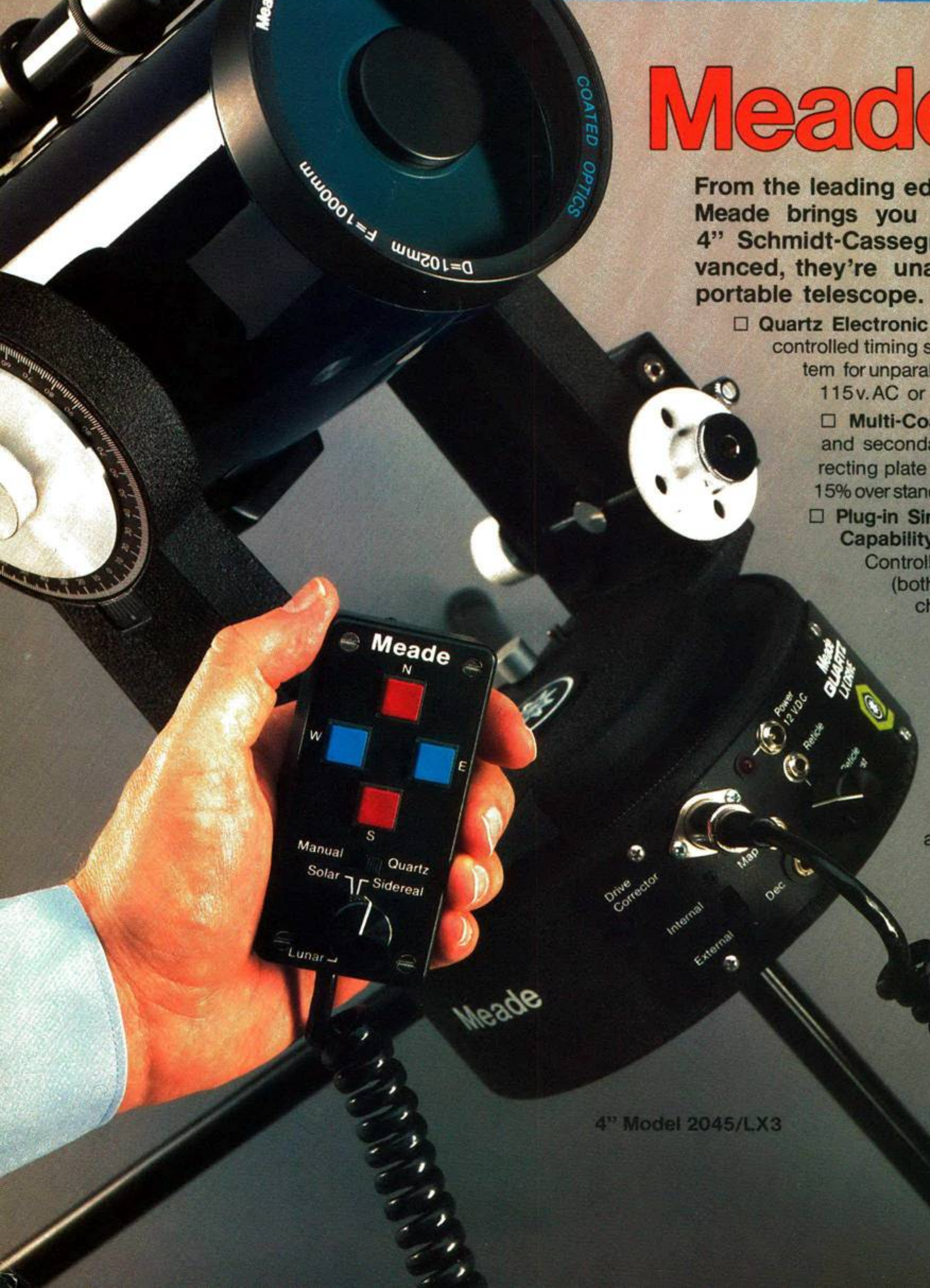
Meade SCHMIDT CASSEGRAIN f/10
COATED OPTICS
D=102mm F=1000mm
Meade
N
W
E
S
Manual
Quartz
Solar
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Meade

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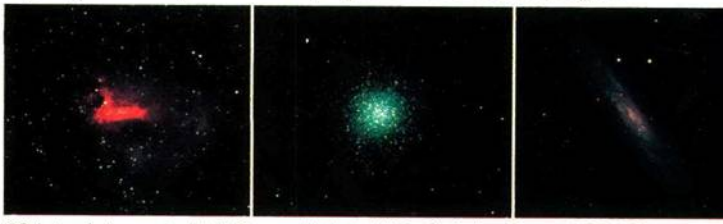

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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